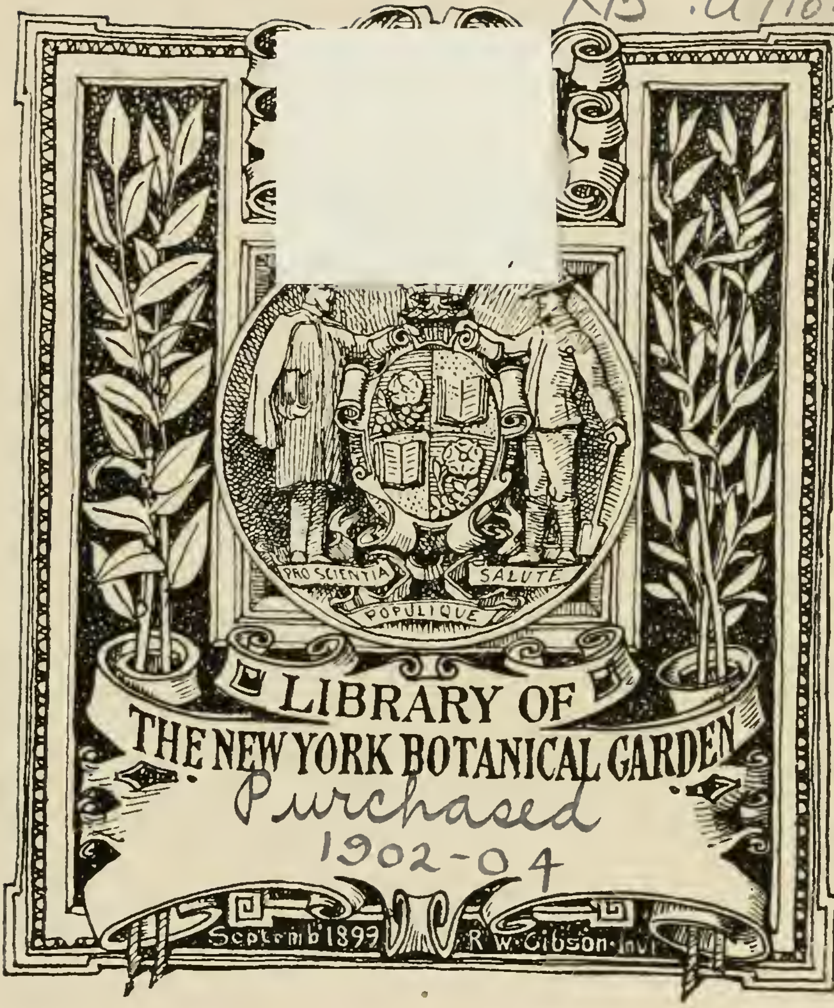
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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 38.

B. T. GALLOWAY, *Chief of Bureau.*

FORAGE CONDITIONS AND PROBLEMS IN EASTERN WASHINGTON, EASTERN OREGON, NORTH-EASTERN CALIFORNIA, AND NORTH-WESTERN NEVADA.

BY

DAVID GRIFFITHS,
Assistant in Charge of Range Investigations.

GRASS AND FORAGE PLANT INVESTIGATIONS.

Issued July 3, 1903.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1903.

BULLETINS OF THE BUREAU OF PLANT INDUSTRY.

The Bureau of Plant Industry, which was organized July 1, 1901, includes Vegetable Pathological and Physiological Investigations, Botanical Investigations and Experiments, Grass and Forage Plant Investigations, Pomological Investigations, and Experimental Gardens and Grounds, all of which were formerly separate divisions, and also Seed and Plant Introduction and Distribution, the Arlington Experimental Farm, Tea Culture Investigations, and Domestic Sugar Investigations.

Beginning with the date of organization of the Bureau, the several series of Bulletins of the various divisions were discontinued, and all are now published as one series of the Bureau. A list of the Bulletins issued in the present series follows.

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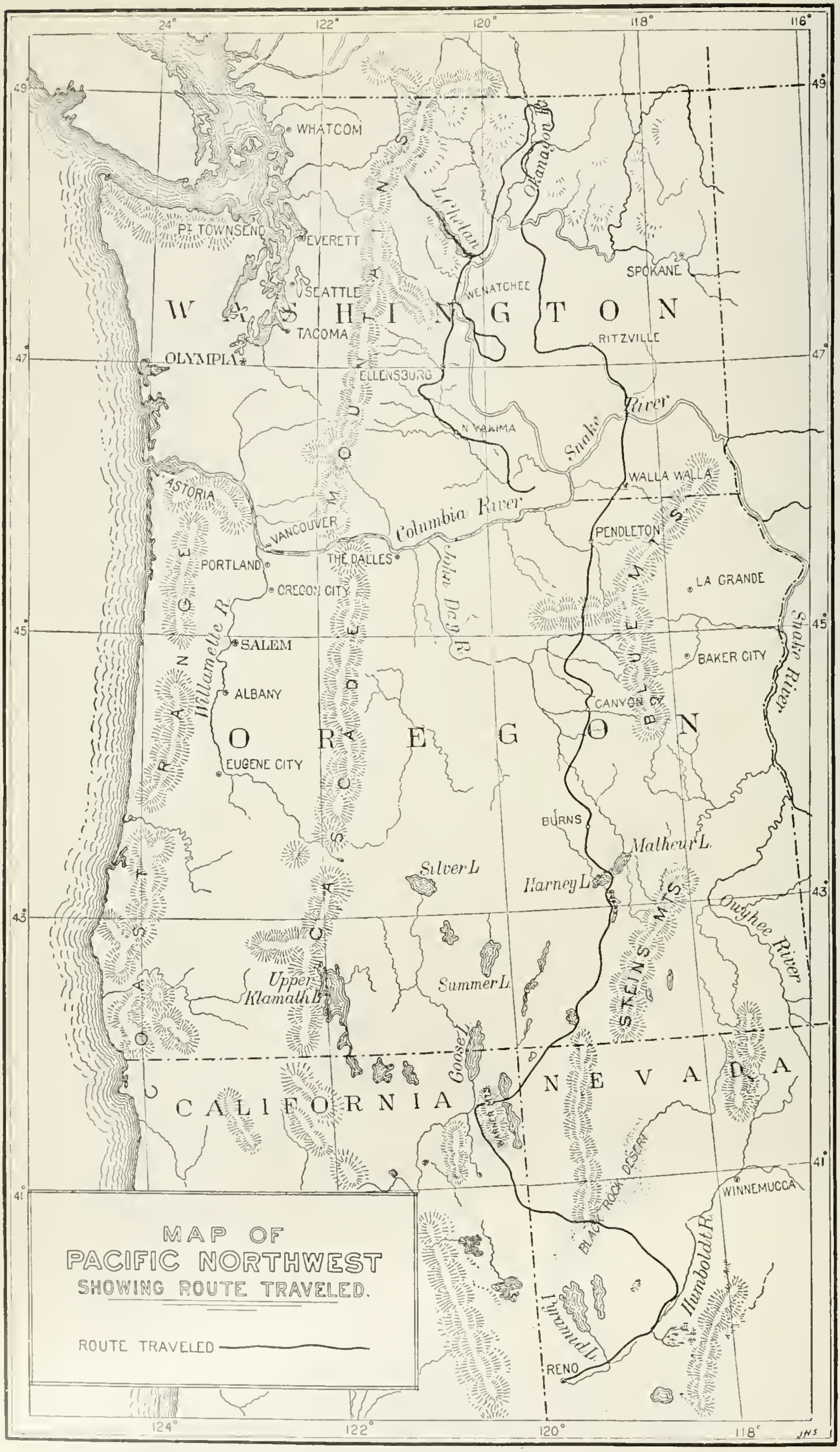
[Continued on p. 3 of cover.]


MAP OF
PACIFIC NORTHWEST
SHOWING ROUTE TRAVELED.
ROUTE TRAVELED
WASHINGTON
OREGON
CALIFORNIA
NEVADA
WHATCOM
PT. TOWNSEND
EVERETT
SEATTLE
TACOMA
OLYMPIA
ELLENSBURG
WENATCHEE
SPOKANE
RITZVILLE
N YAKIMA
WALLA WALLA
ASTORIA
VANCOUVER
PORTLAND
THE DALLES
OREGON CITY
PENDLETON
LA GRANDE
SALEM
ALBANY
BAKER CITY
CANYON CY
EUGENE CITY
BURNS
Malheur L.
Harney L.
Silver L.
Summer L.
Upper Klamath L.
Goose L.
WARNER MTS
BLACK ROCK DESERT
WINNEMUCCA
Humboldt R.
Pyramid L.
RENO
Columbia River
Snake River
Owyhee River
Willamette R.
John Day R.
Okanagon R.
L. Chelan
CASCADE MOUNTAINS
COAST RANGE
BLUE MTS
STEINS MTS
49°
47°
45°
43°
41°
124°
122°
120°
118°
116°

U. S. DEPARTMENT OF AGRICULTURE.

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BUREAU OF PLANT INDUSTRY.

BEVERLY T. GALLOWAY, *Chief of Bureau.*

GRASS AND FORAGE PLANT INVESTIGATIONS.

SCIENTIFIC STAFF.

W. J. SPILLMAN, *Agrostologist.*

A. S. HITCHCOCK, *Assistant Agrostologist in Charge of Cooperative Experiments.*
C. R. BALL, *Assistant Agrostologist.*
DAVID GRIFFITHS, *Assistant in Charge of Range Investigations.*

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., March 17, 1903.

Sir: I have the honor to transmit herewith a report upon "Forage Conditions and Problems in Eastern Washington, Eastern Oregon, Northeastern California, and Northwestern Nevada," and respectfully recommend that it be published as Bulletin No. 38 of the series of this Bureau.

This paper was prepared by Dr. David Griffiths, Assistant in Charge of Range Investigations, Grass and Forage Plant Investigations, and has been submitted by the Agrostologist with a view to publication.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

This is the third paper in the series prepared by Dr. Griffiths bearing on the general subject of range management, two previous reports having been published as Bulletins of the Bureau of Plant Industry, Nos. 4 and 15. The present report discusses existing conditions on the ranges of eastern Washington, eastern Oregon, northeastern California, and northwestern Nevada, points out the causes which have led to the present depleted condition of most of the range country, and suggests needful changes in present methods of utilizing the scanty feed to be found on most of the nonarable lands of the West.

It is noteworthy that the one factor which has contributed more than any other to the depletion of the ranges is the development of hay production on irrigated land in the range region. As long as stock was compelled to subsist the year round on the range, the limited supply of winter feed rendered it impossible to support enough stock to make serious inroads on the more abundant summer growth. The forage plants of the ranges were thus permitted to make seed. But with the advent of hay for winter feed the amount of stock that could be handled increased till in many places the summer growth on the range was entirely consumed, leaving no chance for the production of seed. As a result many thousands of acres of land that formerly furnished abundant pasture are now devoid of any growth that stock will eat, while plants of no value and which are not disturbed by the grazing stock have spread rapidly over these areas.

It is clear that suggestions for the improvement of range conditions to be of value must come from those who are not only familiar with the condition of the ranges, but who also understand the conditions under which stock must be handled on the range. In obtaining the material used in preparing this paper, Dr. Griffiths has traveled 1,700 miles in the range country, mostly by wagon, but no small part of this distance has been covered afoot. On this journey every stockman on the route was interviewed, and in this way much valuable information was collected.

Acknowledgments are tendered to Mr. J. S. Cotton, of the Washington State Experiment Station, who accompanied Dr. Griffiths in his travels over the ranges in that State, and to Prof. Byron Hunter, of the Idaho State Normal School, who rendered similar service in Oregon and Nevada.

W. J. Spillman,
Agrostologist.

Office of the Agrostologist,
Washington, D. C., March 8, 1903.

CONTENTS.

ILLUSTRATIONS.

FORAGE CONDITIONS AND PROBLEMS IN EASTERN WASHINGTON, EASTERN OREGON, NORTHEASTERN CALIFORNIA, AND NORTHWESTERN NEVADA.

INTRODUCTION.

This report, based upon field work done in 1902, is in large part supplementary to that of 1901. The investigations of this year have been confined to the same general drainage regions, but the amount of travel performed and the consequent opportunity for study have been much more extensive. All the work covered in this report, as well as in that of last year,[a] was done in two of the great inland regions, namely, the drainage area of the Columbia River and that of the Great Basin. Last year's report covered but little of the former area, being confined mainly to that portion of the Great Basin region lying between Winnemucca, Nev., and the Blue Mountains of Oregon in the vicinity of the upper portion of the Silvies River, while this report deals with the Columbia drainage area and that portion of the Great Basin lying to the westward of the region discussed in the report of last year. The only place where the same area was covered both seasons is in the vicinity of Burns, Oregon. This duplication of region traversed was occasioned by the necessity of obtaining supplies and the desire of visiting again certain portions of Harney Valley which it was impossible to examine last year. Here, in the vicinity of the Dunder and Blitzen River, on the west side of Steins Mountains, many substantial and extensive improvements are being made, especially by the French-Glenn Live Stock Company, in the handling of the native ranges, as well as in the reclamation of the extensive swamp lands, producing at the present time nothing but tules, but which are being converted into hay and pasture lands.

Our traveling outfit consisted of a team, light spring wagon, and an ordinary camping outfit. On the entire trip, wherever possible, we endeavored to drive about 30 miles per day and to accomplish this in the morning, taking the afternoon to make collections, for studies, and for other work, while our horses, which were obliged to pick

[a] Bulletin No. 15, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1902.

their roughage, were feeding. This, together with the work done from the wagon and an occasional stop of a day or a week in certain important localities, enabled us to gain the desired information and at the same time to cover a large amount of territory. Our plans, of course, had to be modified very materially when crossing some of the deserts in July and August on account of the scarcity of water. Here it was necessary to drive from one watering place to another in the shortest time possible.

Traveling a large part of the time over unfrequented roads, with the exception of about 200 miles in range country, it was possible to do a great deal of work from the wagon, making frequent stops as occasion seemed to demand. This was especially true of our trip through the Blue Mountains of Oregon and the Warner Mountains of California, where we were without any well-defined roads for a good part of the way.

ITINERARY.

After spending two days at Prosser, Wash., and taking a short trip into the "Horse Heaven" country, we started northward (Pl. I), having as our destination the Okanogan region, in the northern part of the State. This we reached by way of North Yakima, Ellensburg, Wenatchee, Chelan, Conconully, and Loomis. On this portion of the trip we were on the west side of the Columbia and Okanogan rivers, in a region the greater part of which may be said to represent the dividing line between the summer and the winter grazing grounds. Frequent stops were made along this route, the longer ones in the Kittitas Valley, near Ellensburg, and at Wenatchee and Loomis. From Chelan a four days' trip was taken to Stehekin, and from Wenatchee a similar one into the Big Bend country at Trinidad. The northern limit of the trip was at a point on the Okanogan River about 8 miles from the British border.

On the return trip most of our time for the entire distance to Conden's Ferry was spent on the Colville Indian Reservation. From Conden's Ferry, on the Columbia River, we crossed over the High Plateau of the Big Bend to Steamboat Rock in the Grand Coulee, which we followed as far as Coulee City; thence southward to the west side of Moses Lake, and thence eastward to Ritzville, in the center of the well-developed wheat region. From Ritzville we went southward along Cow Creek, crossing Snake River at the mouth of the Palouse, and thence via Prescott to Walla Walla.

On July 5 we started southward via Pendleton into the Blue Mountains of Oregon. Here we traversed the forks of the John Day River, passing en route through Camas Prairie, Long Creek, Fox Valley, John Day, Canyon City, Izee, Bear Valley, and Silvies Valley, and reaching Burns on July 17. From Burns our route passed between

Malheur and Harney lakes, and thence southward along the Dunder and Blitzen River to the base of Steins Mountains. From this point we went southwest across Catlow and Guano valleys and across the northwestern corner of Nevada into the Warner Mountains of California; thence southward to Smoke Creek and eastward into Nevada again, across the deserts of Smoke Creek and Black Rock, and thence southward into the Humboldt Valley near Lovelock. Our next trip of 100 miles was in a general southwesterly direction to Reno, where the work for the season in this region was discontinued.

GENERAL ACCOUNT.

The region indicated in the map (Pl. I) is one of great diversity of climate, elevation, and soil conditions, and a complete account of these features is therefore obviously impossible in such a publication as this. In brief it may be stated that the areas of greatest humidity are located in the Okanogan region and in the Wenatchee, Blue, and Warner mountains. The best grazing areas of the Okanogan region are at an altitude of 1,500 to 2,500 feet; in the Big Bend of the Columbia, 1,000 to 1,500 feet; in the prairies of the Blue Mountains of Oregon and the Warner mountains of California, 4,500 to 6,000 feet, and in the general desert basins of Nevada and Oregon, about 4,000 feet. The annual precipitation of the region in general may be accepted as 5 to 10 inches, but of course there is a great variation in the mountains and in the vicinity of our route from Ellensburg to the British border. Accurate data regarding higher and less accessible localities are, however, very scarce, and it can only be said that in portions of the region the rainfall is much greater than the above figures indicate.

The soils are, for the greater part, basaltic, i. e., derived from disintegrated volcanic rock, and are usually spoken of, especially in the northern half of the region, as volcanic ash. This may be taken to represent the entire Big Bend country, as well as the greater part of the deserts of Oregon and Nevada visited. The Blue and the Warner mountains, as well as portions of the Okanogan "Bunch-Grass Hills," are of stiff, heavy clays which support a different vegetation as well as one which is less susceptible of injury from tramping of stock than the looser ashy soils of the drier and usually lower regions represented by the desert plains and the fertile lands of the Big Bend. In the lower portions of all the basins, as well as in the poorly drained areas along the river bottoms, are situated intensely alkaline stretches; these are especially characteristic of the region traversed between the Blue Mountains of Oregon and Reno, Nev. These areas in this region support no vegetation whatever over extensive tracts and are known locally as "sleek deserts." They are the remains of old or temporary lakes, which receive constant accretions of soluble salts from the basins in which they are situated. They are of themselves of no economic importance for, supporting no vegetation and having no outlets in ordinary times, they can not be profitably drained and deprived of the superabundance of soluble salts. They have an immediate connection, however, with the lands in their drainage basins which are being rapidly reclaimed, as will be shown later.

The topography of the Okanogan country differs from that of the Big Bend mainly in being cut up into rolling grassy hills, which are covered with forests of yellow pine on their shaded and higher slopes. The level ground is comparatively small in extent, and when it occurs on elevated regions, as is the case in large stretches on the Colville Reservation north of Conden's Ferry, it is very likely to be too rocky for cultivation; however, in many places in the so-called "Bunch-Grass Hills" there are areas of arable lands, and along all the waterways, especially the main Okanogan River, there are extensive tracts of good hay land yet to be brought under control.

The Big Bend, although a much more level area, still presents a great diversity of topographical features. It may be briefly described as a table-land, 1,000 to 1,500 feet high, underlaid by basaltic rock. This general plateau has been cut in various places by deep gorges, such as the bed of the Columbia, Grand, Moses, and Black Rock coulees, exposing bluffs of basaltic columns, which are a familiar and attractive sight in all of this region. In many places, usually in close proximity to these gorges and especially in the vicinity of such depressions as Moses Lake, the rock is laid bare, or nearly so, over very extensive areas. These must remain permanent grazing grounds. They are known locally as "scab lands," and are usually cut into shallow ravines, being generally much rougher than those areas where the soil is deeper. The irregularity of the erosive action has resulted in the formation of numerous basin-like depressions, where water accumulates and remains for short periods, especially during the winter and spring, thereby furnishing supplies for range stock at those seasons of the year.

The Blue Mountains of Oregon and the Warner Mountains of California have much in common. They are generally forested, but have at high elevations extensive areas of level or gently rolling lands, either free from timber or only sparsely covered. In these areas, usually designated as prairies or valleys, are found the nuclei of prosperous communities. Among these may be mentioned Camas Prairie, Long Creek, Bear Valley, and Silvies Valley in the Blue Mountains, and Jess Valley in the Warner Mountains. These communities are dependent almost entirely upon the stock industry for their support. The lands in these regions are either fertile mountain soils or rocky areas not susceptible of cultivation. The latter furnish pasturage. The former are cropped, usually with hay crops.

The desert region, which occupies practically all of the area between the Blue Mountains and Reno, Nev., except the Warner Range and the Humboldt and Truckee River bottoms, is, in popular parlance, a huge sagebrush plain, broken by numerous low mountain ranges having little or no timber. Between these mountains are the desert sinks and "sleek deserts" previously mentioned. All except the "sleek deserts" are covered with a shrubby growth of sage, saltbushes, and greasewood, which are often the only vegetation.

As compared with the ranges of the Plains, this region generally presents many striking differences. Here there is never a sod except in very favorable localities along streams, where the sedges and native clovers abound. The grasses are truly bunch grasses, although of many botanical species, and the bunches are invariably separated by intervals of a few inches to several feet. With the exception of comparatively small areas of the more fertile regions of the Big Bend and the high mountains, the entire region is covered with a shrubby growth, which is popularly known as sagebrush. There is a great difference here in the soil texture also, it being much looser and less subject to the erosive action of torrential showers. The great difference from the standpoint of the stockman is the entire absence here of the buffalo grass and the blue grama, which are such important factors in the make-up of the Plains vegetation. When compared with the desert regions of the Southwest, we find a greater similarity, especially in the possession of shrubby vegetation, although this shrubbery assumes in the latter more of a thorny and spiny nature and belongs to a very different class of vegetation botanically. In the Southwest is found a class of grasses resembling more closely those of the Plains region, namely, the gramas, which are not only closely related but often identical with the species which is of such importance on the Plains. In regard to the soil, the southwestern stock ranges resemble more nearly those of the Plains as far as the erosive action of water is concerned, although their mechanical and chemical constitution may be very different. As regards the sod, the region in question closely resembles the Southwest, although the latter resembles the Plains region in the species of grasses which it contains. This fact is probably to be correlated with the meteorological conditions mainly, the sparseness and the bunched character of the vegetation between the Rocky and the Sierra Nevada mountains being brought about more by the limited rainfall than by any other cause. This view appears to be strengthened by the fact that many of the grasses of this general region form a close and compact soil cover when grown under the more humid conditions of the Eastern States. The bunching of the grasses, therefore, is probably to be accounted for by the scarcity of the water supply rather than the inherent characteristics of the grasses themselves.

CHANGES IN THE HANDLING OF THE WASHINGTON RANGES.

During the past few years there has been great progress toward a more systematic handling and at the same time a more stable and permanent adjustment of the stock industry in the region of the Big Bend and the country adjacent to it. In many particulars the changes are radical, and in some instances the industry has been remarkably curtailed, though probably not permanently, for the reduced area devoted to the raising of live stock will doubtless be made, when the new conditions become adjusted, to support proportionally a much larger number of animals than it formerly did.

One of the greatest factors in the production of these changes has been the extension of the wheat areas to include practically all of the tillable land of the entire region, apparently regardless of the rainfall. Large areas west of Ritzville, near Trinidad and Waterville, and in the "Horse Heaven" country have in recent years been reclaimed for wheat culture. Some of these areas may not be permanently occupied by wheat, since the average annual rainfall on some of them is less than 10 inches, and some of the more conservative farmers think they will eventually revert to the range.

But the most important factor in these changes has been the agitation brought about in recent years in favor of the passage of a lease law by the National Congress. This agitation, though it has not crystallized into any definite action, has induced many of the nomadic sheepmen, who heretofore owned no land, to invest in lands in anticipation of the enactment of lease laws, which, in all bills thus far introduced, give preference to the actual holders of landed interests. The presence of large areas of railroad land in this region has enabled many to secure from the transportation companies, by lease or purchase (usually the latter), tracts of land suited to their needs. Of course much of this purchase is purely speculative, but a very large proportion of the land so acquired has been bought by those who are and have been for years in the stock business on the public domain. As the railroad land consists of alternate sections, the ownership of these tracts virtually gives the investor control of the adjacent sections of the public domain. As is well known, our homestead laws do not adequately meet the necessities of the man who proposes to embark in the stock business in the semiarid regions, particularly where the railroads own alternate sections. Even a whole section of land is too small a unit for range operations, so that a homestead can only be used as a base for a stock range in cases where all the surrounding lands are a part of the public domain. Indeed, the farmer who raises wheat in this region needs more land to obtain a reasonable compensation for his labor than he can secure under our land laws. In recent years most of the land within the railroad grant has been brought under individual control, and the open-range question is here practically a thing of the past. The greater part of this area is still unfenced, and the boundaries of the different possessions are only approximately maintained, but much of the land is being fenced, section by section, which permits systematic pasturing. This change has yielded results far beyond the expectations of the ranchers.

In one case which came under observation it was estimated by a rancher that the land under his control had increased in grazing capacity about 50 per cent during the past two years, with no decrease in the number of cattle carried on the entire area. One section is pastured at a time, and grass is allowed to attain considerable growth before being pastured, instead of being grazed close to the ground all the time.

In another instance in the same vicinity a year's rest of two and a half sections of pasture land had yielded marvelous results. This land had formerly been grazed by sheep, and the pasture had become so short that the owner disposed of it to the present occupant, who proposed to embark in the cattle business. He allowed his land to rest one year with practically no stock upon it; the gain in feed was remarkable.

Much of this land is used as winter ranges for sheep, which are either herded during the summer months in the mountains to the westward or pastured on the fallow lands in the wheat-growing regions to the east. This treatment will probably increase the capacity of these ranges to a maximum in a few years, provided the summer season of rest is sufficiently prolonged. It is very important in handling these lands as winter pastures not to keep stock on them too late in the spring. In this region the growth of vegetation occurs only in the spring, and stock are sometimes unable, on account of snow, to get into the mountains soon enough to allow much recuperation after the season of grazing before the advent of the dry season, which begins not later than June.

CONDITION AND PLANTS OF THE RANGE.

The best range seen on the entire trip, and indeed the best open range the writer has seen since the early nineties (with the possible exception of the Clear Creek region in the Big Horn Mountains of Wyoming in 1898), was that of the Okanogan hills in northern Washington. The generally good condition of the feed in this region is due to the fact that the country for various reasons has not been overstocked. A large part of this area is occupied by the Colville Indian Reservation, and some of the lands along the river are taken up by Indian allotments which have not been improved to their full capacity for hay production. The length of the winters, the heavy snowfall, and the comparative inaccessibility of the region have all contributed to its protection in the past. It is essentially a summer range, and all stock wintered here must be fed for much longer periods than in the warmer and drier regions to the southward. Up to a year ago summer grazing had been practically confined to stock owned by actual settlers, who have not been able thus far to raise sufficient winter feed to support enough cattle to overstock the summer pastures. Doubtless a very important factor in the preservation of the range has been the persistency with which the settlers have prevented sheep from entering the territory. The development of the river bottoms into meadows which will furnish large quantities of hay and the advent of large numbers of sheep during the past summer will no doubt change the appearance of the native pastures very materially in the next few years.

The main forage plants on the ranges in the Okanogan region do not differ materially from those to the southward in the Big Bend except in the relative quantity of feed produced by the different species. The rolling hills are covered with a luxuriant growth of sheep fescue (*Festuca ovina*), bunch wheat grass (*Agropyron spicatum*), Wheeler's bluegrass (*Poa wheeleri*), and Sandberg's bluegrass (*Poa sandbergii*) on the more rocky and gravelly soil. Nevada bluegrass (*Poa nevadensis*) and prairie June grass (*Koeleria cristata*) are also important factors everywhere above the river bottoms, while giant rye grass (*Elymus condensatus*) occurs in large patches along the sides of depressions on broad, level upland areas, as well as on the edges of the more moist lands along the river bottoms. Along ravines and sandy creeks and river bottoms, bunch wheat grass and giant rye grass are prominent in the lower altitudes, but the bulk of the forage is made up of the needle grasses (*Stipa williamsii* and *S. columbiana*), with the introduced weedy brome grasses (*Bromus tectorum*) and chess (*Bromus secalinus*) in the lower draws and benches, where the native grasses have been injured by the trampling of stock on their way to and from feeding grounds and water. On all of the lower sandy benches just above the river bottoms, especially those of the Okanogan and Columbia rivers, the feed is naturally poor, as would be inferred from the presence of the needle grasses and the bromes previously mentioned. Occasionally the stiffer soils are found on these benches, and bunch wheat grass (*Agropyron spicatum*) is always found in such situations, adding very materially to the feed; but in general these benches are taken up by species of rather inferior quality. Here also are found large areas of plantain (*Plantago purshii*), which closely resembles the Indian wheat (*P. fastigiata*) of the Southwest, but is of much less value, probably owing to the fact that feed is more plentiful here and stock are not forced to subsist upon it. Two other annuals (*Festuca microstachya* and *F. octoflora*) of less value are found on these benches especially, but are also scattered more or less throughout the region.

At the present time the forage plants other than grasses are of little consequence. As sheep are introduced the shrubbery and weedy plants will be utilized to a greater extent, as they are elsewhere in open-range regions; even the clovers appear to be of little consequence here. It must be stated, however, that the observations were made entirely too early in the season to estimate the value of this class of vegetation. Even in the Kittitas Valley and the Wenatchee Mountains, where these plants are of considerable importance, both as hay and pasture, the season was not far enough advanced to enable one to judge of their value. The black sunflower (*Wyethia amplexicaulis*), balsam root (*Balsamorrhiza sagittata* and *B. careyana*) are utilized for pasture to some extent, especially by horses. These plants are of most importance, however, in the region lying to the southwest, especially the Kittitas and Wenas valleys. On the range they are often grazed quite closely by sheep, but all kinds of stock feed on the flower heads and the fruit wherever they are found.

The Big Bend region naturally presents a great diversity of conditions. Some of it is covered with an almost pure growth of bunch wheat grass, while other areas have a mixture of fescues and bluegrasses, and still others have but little grass and are covered with a heavy growth of sagebrush. Part of the area is still open range, while part is systematically handled; consequently this locality presents the greatest diversity in feed conditions. On all the unprotected range visited the feed was very short. The greatest amount of unprotected country seen was in the vicinity of the mouth of the Palouse River, where there was practically no grass, and even plantain (*Plantago purshii*) was extensively grazed in places. Along Cow Creek, however, where the grazing lands are on "scab" between two wheat regions and for the most part are under private control, there was a very evident difference between the open-range and the fenced areas. In that part of the high plateau between the Columbia River and the Grand Coulee which we visited there was excellent feed, owing to the recent invasion of that portion of the country by the wheat grower and the inaccessibility of the remaining range to the general range herds. The grasses here are practically the same as those on the Colville Reservation. Here, however, there is but little shrubbery, the area being a rolling table-land, covered with a luxuriant growth of bunch wheat grass, Nevada and Wheeler's bluegrasses, sheep fescue, and prairie June grass. In places there was some black sage (*Artemisia tridentata*) and rayless golden-rod (*Bigelovia graveolens*) scattered over the lower areas and sides of ravines, but the sagebrush was not prominent on the high elevations. After reaching the Grand Coulee, however, we were never out of sight of sagebrush until the wheat region west of Ritzville was reached. In many places on the lower, well-drained slopes, there were large patches of giant rye grass (*Elymus condensatus*), while bunch bluegrass (*Poa lævigata*) is of considerable value on the lower portions of the depressions.

The Grand Coulee, which crosses the Big Bend country from north to south, is a deep gorge, 1 to 3 miles wide, and was the bed of the Columbia River during the glacial period. The portions of this coulee visited are in most cases very alkaline. In places there is some seepage from the bluffs which has washed the salt out of the soil over limited areas, and these produce good crops of hay. In the vicinity of the numerous ponds only salt-loving plants are found. In one place was seen a large area, half a section or more, covered with creeping spike rush (*Eleocharis palustris*), which was practically the only forage plant growing in this hay meadow. In the vicinity of the numerous ponds salt grass (*Distychlis spicata*) abounds, and grease wood is always found a little farther from the ponds, while on the better-drained lands the common sagebrush is the most conspicuous vegetation everywhere. The saltbushes (*Atriplex* spp.) are of little account here as compared with the Great Basin region to the south. As would be expected in such a formation and with such physical features, conditions are quite variable. One runs into unexpected areas of grass in pockets in the bluffs where the vegetation is wholly different from anything found for miles around. As an example, might be mentioned a shelf-like recess in the bluffs on the north side of the coulee, where there was an excellent stand of water foxtail (*Alopecurus geniculatus*) covering an area 2 or 3 acres in extent. Usually this grass is not abundant enough to attract much attention anywhere.

On nearly all of the "scab" lands from here south along our route to Trinidad, as well as at other points in the Kittitas and Wenas valleys west of the Columbia River, the black sage of the mountains (*Artemisia arbuscula*) predominates over the common black sage of the lower, more sandy soils. Here also there are large areas of the valuable species of sage known to botanists as *Artemisia rigida*. This differs from the other two closely related species in having finely divided leaves and in being relished by stock, more especially by horses and sheep. It was especially abundant at Trinidad, on the western exposure of the Kittitas Valley, between Ephrata and Moses lakes, and in the vicinity of Lyons Ferry. In all of these localities it showed evidences of being grazed during the past winter.

As far as observed, the areas which have been opened up to wheat culture are not particularly sagebrush lands. On the contrary, they are what is commonly known as bunch grass (*Agropyron spicatum*) lands, and the shrubbery, when there is any, is mainly the rayless golden-rod (*Bigelovia graveolens*), which is also sometimes called sage. This was the main shrub on nearly all of the wheat lands traversed, especially in the Ritzville and Walla Walla regions. West of Ritzville, however, at the present time wheat ranches are being opened up very rapidly on the sandy sagebrush lands 8 or 10 miles east of Moses Lake. We did not, however, see the establishment of wheat on these sagebrush areas, and it remains to be proved whether the experiments in wheat growing conducted there will be permanently successful.

From the standpoint of quantity, bunch wheat grass (*Agropyron spicatum*) is without doubt the most important grass in the Big Bend region, although the bluegrasses and sheep fescue heretofore mentioned are of much prominence on the higher elevations as well as on the "scab" lands. Owing to the rapid extension of the wheat area, the localities where this grass grows pure are rapidly diminishing in number. It may be said that the form of the grass which is so important here is that designated by botanists as *Agropyron spicatum inerme*, which is so named from the fact that the chaff which incloses the seed is without awns. As one proceeds southward even a short distance into the Blue Mountains, the awned form appears and the awnless one is almost, if not quite, absent.

Attention was called in last year's report[a] to the two forms of sheep fescue in the mountains of Nevada, and it was stated there that they often grow in nearly distinct areas, the glaucous form at higher elevations than the smooth variety. The two forms are found here also; but, although well marked, they have not been observed in separate areas as in the southern desert mountains. As far as forage value is concerned, there is no apparent difference in the two forms.

Although several newly established wheat areas were passed through, there were but two well-established ones on our route. The first extended from about 20 miles west of Ritzville to the "scab" along Cow Creek; the second, from about 8 miles south of Lyons Ferry to Pendleton, Oregon. The developing areas are located at Trinidad, on the high table-land south of Conden's Ferry, and at Ephrata. All the remainder of the territory traveled over in the State is devoted to cattle raising, and all is pasture land except such regions as North Yakima, Wenas, and Kittitas valleys, and small areas in the vicinity of Conconully and Loomis and along creeks emptying into the Columbia River, which are devoted mainly to the culture of hay crops under irrigation.

The poorest "scab" land vegetation is well illustrated by a collection made south of Ephrata, near the Ferguson ranch. The shrubs were by far the most abundant form of vegetation. They consisted

[a] Bulletin No. 15, Bureau of Plant Industry, U. S. Dept. of Agriculture, 1902, p. 52.

of the eriogonums (*Eriogonum dichotomum*, *E. sphærocephalum*, and *E. thymoides*), tetradymia (*Tetradymia canescens*), audibertia (*Audibertia incana*). gilia (*Gilia pungens*), black sage (*Artemisia arbuscula*), and a little *A. rigida*. Of these the eriogonums and *Artemisia rigida* are of economic value. The former are especially useful as a browse for sheep, as undoubtedly nearly all of the species of this genus are when good feed is scarce. The herbaceous vegetation, aside from the grasses, consisted entirely of a scattering growth of *Gayophytum ramosissimum* and *Lygodesmia juncea*, both of which are of some importance as sheep feed. The grasses were few, scattering bunch wheat grass (*Agropyron spicatum*) being the most important, while there was an occasional bunch of needle grass (*Stipa thurberiana*) growing up through the bunches of shrubs. Fescue (*Festuca microstachya*) occurred in very small quantities, and some of the root leaves of Sandberg's bluegrass (*Poa sandbergii*) were in evidence where protected by rocks. It is to be understood, of course, that the above represents the vegetation at the time of observation (July). In the spring there are other short-lived species which furnish some feed. On the better classes of "scab" lands, along Cow Creek and south of Trinidad especially, sheep fescue and the bluegrasses (*Poa nevadensis* and *P. wheeleri*) are more abundant.

The condition of the feed in the Blue Mountains of Oregon was variable, even in areas where meteorological conditions as well as altitude are very similar. This is due entirely to the method of handling the ranges. In the vicinity of the mountain settlements where sheep are excluded the condition of the grazing lands is much better than in the open country. The "dead lines" established by the ranchers, usually on the watershed of the valley, although not always rigidly maintained, have done much to preserve the original vegetation, for it is not as closely eaten off by cattle, a few of which are possessed by every rancher, as by the immense flocks of sheep which are driven into these mountains from all directions. The great stretches of desert range almost surrounding these mountains furnish abundant winter pasturage for sheep, but the summer supply for the growing lambs in the mountains is comparatively limited. The Blue Mountains, therefore, have been the battle ground of conflicting stock interests which have striven for the past twenty years for the major share of the free grass. The homesteader, by protecting small tracts about him, has improved conditions wonderfully in limited areas. But those areas which are not subject to individual control have been so closely pastured that there is no more feed in some localities than on the deserts below. Plate V, figure 1, shows a moist meadow on the north slope of the mountains where there should be, and where there was formerly, a luxuriant growth of grasses, clovers, and sedges, but which is now all but barren of vegetation. A complete collection of the plants which grew here showed not a single perennial and no annuals over 2 inches in height. These had apparently developed from seed during the previous month, after the sheep had been moved to higher altitudes. The reduction of a sedgy mountain meadow to an almost bare surface, where nothing is to be found but stunted plants of *Navarretia breweri*, *Linanthus harknessii*, knotweed (*Polygonum douglasii*), *Eritrichium californicum*, *Matricaria discoidea*, and burnet (*Poterium annuum*), is a condition much to be deplored, and is certainly not conducive to the best interests of the stock industry. In sheep territory it can be stated that there are few shrubs, aside from the snow brush (*Ceanothus velutinus*) and a few of the phloxes and gilias, in these mountains which are not browsed; and the timber does not grow too thick for sheep to graze in. Even the second growth of pine (*Pinus ponderosa*) is browsed in many places.

The forage plants, especially the grasses, do not differ materially from those of the higher elevations in eastern Washington previously discussed. The conditions are mostly such as would be recognized only by the critical student of grasses. Bluegrasses (*Poa nevadensis*, *P. wheeleri*, *P. sandbergii*, and *P. buckleyana*), sheep fescue (*Festuca ovina* in both its forms), bunch wheat grass (*Agropyron spicatum*), prairie June grass (*Koeleria cristata*), short-awned brome (*Bromus marginatus*), orchard barley (*Sitanion longifolium*), giant rye grass (*Elymus condensatus*), tussock grass (*Deschampsia cæspitosa*), and needle grass (*Stipa viridula* and *S. thurberiana*) are the main species on the open areas, while in upland shady places and in brush and timber areas are to be found a form of Kentucky bluegrass (*Poa pratensis*), downy oat grass (*Trisetum subspicatum*), oat grass (*Danthonia californica*), melic grass (*Melica subulata*), and mountain rye grass (*Elymus glaucus*), together with pine grass (*Carex geyeri*), which constitute the main feed in these localities at an altitude of 4,500 to 6,000 feet. On some of the bare, rocky slopes on the open range occurs some clover (*Trifolium plumosum*). This is seldom so abundant that seed could be collected in quantity. Its strong root system and general habit in barren soils would lead one to believe that it might be of some value on the upland ranges if some method could be devised for its propagation so that seed could be collected advantageously. Along all the creeks and moist areas throughout the region fine feed is produced by other species of native clovers (*Trifolium beckwithii*, *T. cyathiferum*, *T. altissimum*, and *T. involucratum*), while in the same localities there are many species of sedges and rushes which are really of more importance than the grasses in many situations. In these more moist localities are also found mountain timothy (*Phleum alpinum*) and whitetop (*Agrostis asperifolia*).

The numerous pastures in the vicinity of the settlements are used almost entirely for winter grazing, the stock feeding upon the open ranges during the summer season. When not pastured too late in the spring, these were in good condition. Very often they appear overstocked, with the result that the weedy plants predominate to a remarkable degree. A collection of plants made in one of these mountain pastures in Camas Prairie will illustrate the effect of too close grazing, especially when the frost is going out of the ground in the spring. This was an open, rocky meadow, with stiff clay soil. There was here originally a good pasture of Sandberg's bluegrass, bunch wheat grass, sheep fescue, Wheeler's bluegrass, Nevada bluegrass, and prairie June grass. These are now very thin and scattering, having been trampled out to a large extent in late May and early June when no stock should have been allowed in the fields on account of their soft and miry condition. The following species were the abundant and conspicuous plants in the pasture: Yarrow (*Achillea millefolium*), black sunflower (*Wyethia amplexicaulis*), arnica (*Arnica alpina*), erigeron (*Erigeron aphanactus*), gaillardia (*Gaillardia aristata*), balsam root (*Balsamorrhiza incana*), lupine (*Lupinus sulphureus*), *Clarkia pulchella*, onion (*Allium madidum*), *Navarretia breweri*, phlox (*Phlox gracilis*), gilia (*Gilia aggregata*), eriogonum (*Eriogonum heracleoides*), geum (*Geum trifolium*), *Pentstemon attenuatus*, *Scrophularia orthocarpus*, *Deschampsia calycina*, knotweed (*Polygonum douglasii*), *Lomatium leptocarpum*, calochortus (*Calochortus nuttallii*), and *Sedum douglasii*. Practically all of these were in bloom when the collections were made, and the field had the appearance of a flower garden rather than a pasture.

A similar substitution of native plants of little or no forage value for the true grasses is common in the region, as well as in similarly treated areas in the more moist regions of Washington. Such substitutions are usually more noticeable in humid mountain areas than on the lower deserts, for, in the latter, when the scattering bunches of grasses are killed out, there is often nothing to take their place. One of these overgrazed native pastures in the wheat region west of Ritzville, Wash., is shown in Plate IX, figure 1. For a list of the shrubs grazed by sheep the reader is referred to subsequent pages, which discuss the conditions in the Warner Mountains of California, and to Bulletin No. 15 of the Bureau of Plant Industry, U. S. Department of Agriculture. It may be stated that no black sage was seen in the Blue Mountains, except small patches of *Artemisia arbuscula* on the north slope, until Bear Valley, near the Great Basin drainage, was reached.

As far as general vegetation is concerned the Warner Mountains of California do not differ materially from the Blue Mountains of Oregon; at least the main features are the same, and the general topographical features are very similar. The water supply, however, is much better in the mountains first mentioned. Indeed, it would be difficult to find an open range region where water is better distributed than in the

Warner Mountains to the east of Jess Valley. These conditions have been taken advantage of to a detrimental extent by the immense flocks of sheep which winter on the deserts to the southward and eastward in Nevada and Oregon. One characteristic feature of those portions of these mountains is the abundance of browse plants, which make them especially attractive to the sheep grower. Sheep need a change of ration in order to thrive to the best advantage, even if that change be to weedy pastures, which are ordinarily considered of little value. Often they appear to be benefited by such a change from a good grass pasture. This testimony of the herder is substantiated by the fact that when grass is abundant the sheep will feed on such bitter plants as the willow, poplar, and some of the so-called sunflowers previously mentioned. In this region such shrubby plants as the gooseberry (*Ribes lacustre*, *R. luteum*, *R. cereum*, and *R. aureum*), snowberry (*Symphoricarpos oreophilus*), willow, poplar, mountain ash (*Pyrus sambucifolia*), service berry (*Amelanchier alnifolia*), and *Purshia tridentata* are very abundant. At the time of this visit immense numbers of sheep were practically subsisting on these plants. There really was no grass. Even the banks of the rivulets were chopped up by the incessant tramping, and the steep hillsides, protected by jagged rocks, were dusty. The writer has never seen a more deplorable condition than existed here. The sheep region was visited about the 1st of August, and sheep were supposed to remain there two months longer. It is difficult to imagine what the animals could find to live on. On an area shown in Plate VI, figure 2, the snowberries had been cropped so that there was nothing left but short, barked stumps and old, woody stems. This is in the vicinity of an old corral, but photographs taken in the same region show that similar conditions exist over a large part of the mountains.

The range regions traversed between the Blue Mountains, in Oregon, and Reno, Nev., with the exception of the Warner Mountains, have much in common. The mesa region does not differ greatly in appearance, although the black sage of the northern part is almost entirely replaced to the southward over large areas, especially in the vicinity of the Black Rock and Smoke Creek deserts, as well as in the Humboldt Valley, by the saltbushes, hop sage, bud sage, red sage, and white sage. These sage plants are of much more value as winter feed than the saltbushes. In this general region eight sinks were passed over. Some of these had water in them in places, but for the most part they were dry, the surface being smooth, showing level narrow fissures, and having no vegetation. The main areas of this character seen were in the Harney, Guano, and Catlow valleys, in Oregon; Surprise Valley, in California; and Long Valley, Smoke Creek, Black Rock, Humboldt Sink, and White Plains, in Nevada. All of these areas located in the lower portion of their drainage basin have as a first distinct zone of vegetation salt grass (*Distichlis spicata*) and bordering it grease wood (*Sarcobatus vermiculatus*). These are in turn surrounded by the usual shrubs of the desert. In places where the drainage waters empty into the basins the vegetation is of course very much modified. It is here that the ranches occur, and it is upon the impounding of the spring waters which reach these sinks that the reclamation of these deserts depends. These areas, however, are now no part of the range, but they serve for the culture of winter feed for stock and are in the main patented holdings. The condition in the higher mountains was discussed in Bulletin 15 of the Bureau of Plant Industry, U. S. Department of Agriculture, to which the reader is referred.

Surrounding many of these desert sinks a peculiar condition exists as regards the distribution of vegetation. On the edges of the majority of them there are sandy drifts of varying magnitude, in which all of the desert shrubs may be found growing promiscuously. These accumulations of earth are derived from the desert basins during the dry, windy weather, and they are consequently very different from the ordinary sand dune, inasmuch as they, as well as the desert basins themselves, are very alkaline, the salts being blown out during the dry season. The vegetation of one of these dunes in Long Valley, Nevada, will serve as an illustration. There appeared in these mounds grease wood (*Sarcobatus vermiculatus*), black sage (*Artemisia tridentata*), bud sage (*Artemisia spinescens*), hop sage (*Grayia spinosa*), and saltbush (*Atriplex confertifolia*). On the "sleek desert" sides of these mounds occurred a scattering growth of salt grass, sometimes extending over the mounds, while on the edge of the more salty areas were also scattering growths of suaeda (*Dondia depressa erecta*) and iodine weed (*Spirostachys occidentalis*). None of these shrubs except the first mentioned is to be considered a salt-loving plant, but all were able to thrive here, doubtless because they became established before the drifts. For the same reason they are not to be considered sand binders, although they did serve that useful purpose here.

The feed on the desert mesas of Catlow Valley is furnished almost entirely by needle grass (*Stipa thurberiana*), orchard barley (*Sitanion longifolium* and *S. villosum*), prairie June grass (*Koeleria cristata*), wheat grass (*Agropyron* sp.[a] (G. & H. No. 306), Indian millet (*Oryzopsis cuspidata*), and giant rye grass (*Elymus condensatus*). To these should be added Nuttall's saltbush (*Atriplex nuttallii*), which grows here, as is common with this species, almost pure in irregular areas, usually of a few acres in extent, in the general sagebrush mesa. The grasses, it must be understood, are in small scattering bunches, and it would doubtless take more than 50 acres to support a steer for one year on the general mesa. The conditions described in Steins and Pine

[a] This species, although quite abundant, was not secured in proper condition for determination.

Forest mountains in last year's report apply equally to the foothills and mountains here and need not be repeated.

One hundred miles south of this region, in the vicinity of the Black Rock desert in Nevada, the conditions are very different although the general appearance of the two regions is similar. In the more southern locality the black sage is almost absent on the general mesa, being confined to the higher elevations in the hills and mountains, as is the case over large stretches on the gently sloping hillsides surrounding the Black Rock desert, as well as in the vicinity of Lovelock. Saltbush (*Atriplex confertifolia*) is the one desert shrub and practically the only plant in evidence at this time of the year over very extensive areas. The vegetation in the vicinity of Boiling Butte will serve as a representation of the flora. Quite a collection was made here from the "sleek" Black Rock desert to the top of the butte. The first plants in the edge of the deserts are iodine weed (*Spirostachys occidentalis*) and pahute weed (*Dondia depressa erecta*) in bunches along the edges of the desert. These are followed in turn by a scattering growth of salt grass (*Distichlis spicata*), grease wood (*Sarcobatus vermiculatus*), and saltbush (*Atriplex torreyi*). The latter thrives on more alkaline areas than the grease wood. On the general mesa are scattering growths of shrubbery such as saltbush (*Atriplex confertifolia*), bud sage (*Artemisia spinescens*), tetradymia (*Tetradymia spinosa*), red sage (*Kochia americana*), hop sage (*Grayia spinosa*), rayless golden-rod (*Chrysothamnus viscidiflorus*), and white sage (*Eurotia lanata*). All of the mesa plants extend up the side of the butte for a considerable distance and the red sage, hop sage, and white sage, together with *Tetradymia canescens* extend to the very top, where there are also found *Eriogonum dichotomum*, *E. microthecium*, and *E. hermanii*, *Gilia pungens*, bed straw (*Galium multiflorum*), and *Lygodesmia spinosa*. The black sage does not appear except at the higher altitudes about 600 feet above the general mesa. On the buttes there was a little Buckley's bluegrass (*Poa buckleyana*), while Indian millet (*Oryzopsis cuspidata*) was found on the sandy knolls on the mesa. The shrubbery, however, is the most important feed, and all of the varieties mentioned are utilized, with the exception of the rayless golden-rod and the gilia. On the higher Granite Mountains to the northward there is a scattering growth of juniper and, of course, more feed, consisting of species of clovers and sedges, together with the bluegrasses and sheep fescue already mentioned for the region. The feed in the vicinity of the hot spring was in striking contrast to that of the mesa and desert. The most conspicuous plant in the water is bulrush (*Scirpus olneyi*), which is found even in the middle of the stream a short distance from the boiling spring. Farther along where the water was cooler, beard grass (*Polypogon monspeliensis*), *Scirpus americanus*, and prairie bulrush (*Scirpus campestris*) throve. Farther removed from the hot water, and evidently in earth containing considerable soluble salt, were small areas of giant rye grass (*Elymus condensatus*), wild wheat (*Elymus triticoides*), and squirrel tail (*Hordeum jubatum*). Everywhere there was a robust growth of salt grass, which was very heavily covered with the secretion so characteristic of it in this region. All these were, of course, grazed to a large extent. Attention is called to the fact that our animals refused to feed on the salt grass here for the first time, owing, no doubt, to this covering of salt.

In places on the edges of the desert there is another salt-secreting plant *Eunanus bigelovii* (?) (No. 535 Griffiths and Hunter), which the writer has met with several times. It is always most abundant and is most abundantly supplied with the secretion in the vicinity of borax deposits. Last year it was found to be very common near Wild Horse and again at this place. The salt secreted by this plant, however, is very different from that of the salt grass, inasmuch as it assumes a crystaline structure when dry.

About 4 miles from the hot spring mentioned, we came across a very peculiar cool spring in the middle of the Black Rock desert. The area immediately surrounding this spring is interesting in showing the plants that thrive to the best advantage in this strikingly alkaline situation, especially since all those which grow here are of value for grazing purposes. This spring was situated in a hillock about 12 feet high in the middle of the level salt desert. The water formerly broke out at the top of the mound, but now comes from the side and runs only a few feet before it sinks into the ground. There was a scattering growth of salt grass all around the hillock and on the shady side a thick growth of grease wood. The seepage ran out on the desert about 50 feet and sank into the ground. A patch of squirrel-tail (*Hordeum jubatum*) and *Scirpus americanus* was growing in the seepage water. This was practically the only pasturage found for our animals on the entire trip of 100 miles from Deep Hole to Lovelock. The plants specified above formed the only vegetation aside from some of the blue-green algæ forming a scum over the entire surface of the ground, which was kept moist. The water, although cool, was intensely alkaline.

It is to be understood, of course, that the region which was traversed between Smoke Creek and Lovelock is used mainly as a winter range for sheep. There are in this region a few cattle camps, and the Deep Hole Company has control of the Granite Mountain region, in which there is, of course, better feed. In places between Rabbit Hole and Lovelock, and especially eastward from Pyramid Lake, there are very extensive areas of white sage (*Eurotia lanata*) on the mesas and foothills and very often extending into the mountains. The finest areas of this plant seen were located 20 miles or so north of Lovelock and in the vicinity of Rye Patch. This, together with saltbush (*Atriplex confertifolia*), bud sage, hop sage, and red sage, constituted the main browse, while the grass feed is produced mainly by Indian millet (*Oryzopsis cuspidata*) on the lower sandy areas and Buckley's bluegrass (*Poa buckleyana*), Wheeler's bluegrass (*Poa wheeleri*), and a little sheep fescue on the higher areas. Very little of the latter was seen in this vicinity, but it was very abundant in the pine forest mountains to the northeast of here last year.

The condition of the feed now as compared with former times is very difficult to estimate. There has been so little attention paid to the purely winter grazing grounds that there are but few data regarding them. Water is so scarce here that pasturing is possible only when there is a heavy fall of snow, and the character of the vegetation is such that it is of but little value except for winter feed. Consequently the thousands of sheep which winter in the region live on browse of the desert during the winter months. If the snowfall is copious they are able to get down to the mesa, but during dry winters they feed around the summits of the mountains, within traveling distance of snow, which is often their only source of water for several months of the year. It is to be understood, of course, that many flocks of sheep congregate around such places as Lovelock and Carson Sink for the purpose of obtaining hay for a portion of their winter ration, and thousands are driven here to be fattened for the markets. Consequently this desert, which to the ordinary observer has neither feed nor water, is of great importance, for it supplies feed of a coarse kind upon which thousands of sheep pass several months without other expense than herding. As stated in last year's report, there is need of close study of these ranges in the winter season, something which has not yet been attempted.

Although the feed is mainly browse, there occurs somewhat of a change of ration between late fall and spring. The white sage, red sage, hop sage, and saltbush are mainly of value as early winter forage, while the bud sage becomes valuable in late winter, when the bud-like twigs begin to develop, the young leaves and tender shoots being relished by all stock. At this season there are also many winter annuals, which are eaten by sheep especially.

MEADOWS AND HAY CROPS.

The main cultivated crops throughout the region described are four in number—alfalfa, timothy, redtop, and grain. Throughout the entire region alfalfa is the main irrigated crop, especially in the lower areas, while along the higher courses of streams in poorly drained areas timothy and redtop are extensively grown. Grain for hay is the common and prevalent crop in the wheat areas. In the North

Yakima region considerable clover, orchard grass, and Kentucky bluegrass are raised, the latter usually for pasture. While bluegrass thrives here, it is not considered a paying crop for hay, especially when compared with timothy and alfalfa.

ALFALFA.

It is not necessary to go into details regarding alfalfa, as its growth in this general region has recently been discussed at considerable length by a member of the office staff.[a] Some additional points with reference to it, however, are of sufficient importance for record at this time.

It is unusual, especially in the West, to attempt to grow alfalfa without irrigation, but a few experiments observed appear to indicate that production in this way may become of some importance in certain favored localities. Two small areas with no irrigation whatever were seen near Prescott, Wash., which bore much promise. The best of these was on the farm of U. L. Malloy, about 7 miles from Prescott. This had not been cut when seen, but it would yield, apparently, about 2 tons of dry feed per acre. Another area a short distance west of Ritzville, in the same State, also showed considerable promise. Here it was evidently intended to be used as a summer pasture for hogs. The growing of alfalfa without irrigation deserves attention, for there are probably many limited areas in this general region where it can be grown successfully without the aid of an artificial water supply.[b]

The ability of this crop to withstand large amounts of soluble salts in the soil was especially noted at Lovelock. It is truly remarkable what has been done in the upper settlements here in the reclaiming of alkaline desert lands. Much of the best alfalfa land above Lovelock, where the finest crops are now grown, was recently what is popularly known as "hilly grease-wood land," which is always alkaline. This land is characterized by having a rather heavy growth of grease wood and saltbush (*Atriplex torreyana*), with the bushes as a rule situated on mounds 1 to 3 feet high, making of the generally level plain a very rough and uneven surface. Before the land can be handled at all the brush must be gotten rid of and the mounds must be leveled off; then comes the task of getting an alfalfa crop established. To one who is not an expert in alfalfa culture the task would appear hopeless. A grain crop, usually wheat or barley, is raised for one or two years, until the land is subdued, when alfalfa is sown, in the majority of cases without a nurse crop. The surface salt in the heaviest deposits is removed by flooding and draining rapidly just before the seed is

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[a] A. S. Hitchcock. Cultivated Forage Crops of the Northwestern States, Bulletin No. 31, Bureau of Plant Industry, U. S. Department of Agriculture, 1903.

[b] Alfalfa is grown quite successfully without irrigation in the wheat-growing districts of eastern Washington, yielding one and sometimes two cuttings a year.—*W. J. S.*

sown, when this is possible. When once the plants have become established and a soil cover is obtained the battle appears to be nearly won, for with a very moderate amount of water these soils produce much better crops than the lighter better drained nonalkaline areas. Constant care is necessary, however, for the breaking of the soil cover over a small area, due to imperfect seeding or too great an accumulation of salt in the surface layers, soon allows salt grass to get a foothold, and this needs no encouragement in such soil to take possession very rapidly. With such a limited supply of water as has been available during the past few years it has evidently been exceedingly difficult to get a crop established. Mr. A. F. Campbell showed some areas in one of his fields where it took five years to establish the crop. It is a common thing here, it is said, to see portions of a field which raise fine crops having a very noticeable accumulation of salt on the surface in the early spring. This disappears with the establishment of a soil cover. Indeed, several such areas were pointed out, and in one case unmistakable crusts of salt forming after the cutting of the second crop were seen. Of course the margin between success and failure under such conditions is very narrow, but the successful culture of alfalfa on such lands points to this legume as the leading and most promising alkali-resisting forage crop.

The greater part of the alfalfa in the valley is raised for sale, although there are many large holders who feed all and more than they can produce themselves. In August, when this region was visited, the crop was selling at $5 per ton in the stack, or $7.50 per ton baled, f. o. b. at Lovelock. Information from several sources indicates an average yield of 4 tons per acre, and the cost of handling it is estimated at about $6 per acre. This leaves a clear profit of about $14 per acre. It is not surprising under the circumstances that alfalfa land commands high prices, nor is it strange that more land is brought under cultivation than the water supply justifies.

TIMOTHY AND REDTOP.

The methods of handling timothy and redtop, especially along the upper courses of streams and narrow bottoms, and the reasons for the same, are of interest. A very large proportion of these two crops, except in the Ellensburg region, in Washington, along our line of travel from Wenatchee to the British border, in the Blue Mountains, along the Blitzen River, and in the Warner Mountains of California, is raised on uncultivated land. The small amount of labor involved doubtless accounts for this method of handling the crops, but in many localities it is rendered necessary by the difficulty of getting on the land in the mountain regions until very late in the spring, because of the excessively moist condition of the soil. Again, in many situations where magnificent crops of timothy and redtop are raised it is rather risky to plow the ground, for in narrow bottoms through which large volumes of water flow at certain seasons of the year the breaking of the land would result in all loosened portions being carried away by the first freshet. After this, gullying would follow very rapidly. In a state of nature the sedges (*Carex* spp.) and the native clovers form very effective soil binders in these places, and to disturb them without at the same time introducing other plants which serve the same purpose would be hazardous. The feed produced by these sedges, however, is rather small in quantity and often poor in quality, especially when hay is desired. The rancher therefore introduces timothy and redtop and supplants the native forage plants and soil binders without disturbing the soil. There appears to be no established time for seeding. Often the seed is scattered on the snow. Sometimes it is sown in the fall and at other times in the spring, apparently with equally good results. Along the Okanogan River and Cow Creek, in Washington, as well as in the Warner Mountains, in California, many fields of timothy were seen which were established in this way. (Pl. VII, fig. 1.) Some fields yield as much as two and a half tons per acre. Along the Okanogan and other streams in north central Washington there is a great deal of brush, especially willow, alder, and wild rose. The practice is to cut and grub these out, burn the brush, and scatter timothy and redtop seed at the first favorable opportunity. Of course much more seed is required when the land is not plowed, and it usually takes several years to secure a good stand. Along Cow Creek some meadows established twenty years ago on sod are in reasonably good condition to-day, although they have been cut for hay and pastured during the winter every year. The Gundlach Live Stock Company, whose holdings lie between Smoke Creek and the Black Rock deserts, in Nevada, follows the practice of running a clod crusher over its meadows in the spring after the cattle are taken off, in order to break up the manure which would otherwise be raked into the hay the following season. Alsike clover sown with redtop and timothy here seems to thrive better than red clover, and timothy is in time run out by redtop. Neglected and improperly drained meadows are injured very much by the encroachment of sedges and rushes, with salt grass and small cord grass (*Spartina gracilis*) appearing in the more alkaline portions.

The amount of timothy and redtop seed scattered on uncultivated land in this region is very great, some large holders, such as the French-Glenn Live Stock Company, on the Dunder and Blitzen River, and Babcock & Benson and P. H. Schnebly, in the Wenatchee Mountains, using seed in ton lots. The two last-named holders are just inaugurating their experiments and have secured no results, but the first has much hay land established in this way, and its operations in draining swamp lands will result in a very large increase in its meadows in the near future.

In Jess Valley, in the Warner Mountains of California, timothy especially is being introduced, even into the rocky soils surrounding the bottom-land meadows, by diverting the waters from the melting snows to these areas and seeding in the manner already described. Much of this land could never be cultivated, and a large portion of it is altogether too rocky to be mowed without a great deal of labor expended in removing the rocks; but the amount of feed secured from such areas is greatly increased by this treatment. These areas are usually reserved until the hay is removed from the meadows, when cattle or sheep are turned into them for fall and winter pasturing. It is common here, as well as in the other hay regions visited, for hay to be sold in the stack, together with the feed in the field, to be pastured and fed out during the fall and winter as the stockman may wish, or as may be agreed upon.

The methods employed in the irrigation of timothy and redtop in many of the narrow valleys, especially the Okanogan, Cow Creek, Silvies River and its tributaries, and Jess Valley, are very interesting, inasmuch as they show that these grasses under certain conditions are able to withstand large quantities of water for long periods. The method of irrigation is a combination of ditching and damming processes. The flood water in the early summer, May to July, is diverted to the meadows in such a way as to cover them for periods varying from ten days to two or more weeks at a time. Ordinarily this would result in the destruction of these crops and in their being entirely supplanted by the sedges and the rushes. However, there is a large measure of success attained by this method of handling the waters. Being cool at this season and the water being in motion (i. e., flowing water), there is not the usual injurious effect. Neither is the method wasteful of water, for in a narrow valley there is but little loss to the irrigated lands below from having the waters spread out in this way in the upper stream courses. In many cases it is actually an advantage, as the flood waters are checked and distributed over a longer period. It would appear that timothy and redtop grown on meadows which are occupied to a large extent by sedges and native clovers, when handled in the manner described would need much more irrigation than when grown on cultivated land. One of these areas along Silvies River is shown in Plate VII, fig. 2, where these two crops, together with some alfalfa on the better-drained sagebrush areas, are grown.

The most extensive timothy and redtop region visited was that of the Kittitas Valley, at Ellensburg, Wash., from which much hay is shipped every year, mainly to Coast points. The alfalfa shipped from here is sold at about $4.50 per ton, while timothy and redtop sell for about $9.

AWNLESS BROME.

As is well known, one of the greatest brome-grass regions which has been developed in this country since seed of *Bromus inermis* was introduced by the U. S. Department of Agriculture some years ago is the Palouse region in eastern Washington, but the cultivation of this grass does not appear to have spread to the westward and northward to such an extent as one would expect. Awnless brome is grown in a limited way, however, in a few of the localities visited, and in all cases appeared to be promising. From the observations made, there seems little doubt that in the Pacific Northwest it will grow and make good returns wherever wheat can be raised for hay. Near the mouth of the Okanogan River a small area of this grass on irrigated land was seen that would cut at least 3 tons of dry feed per acre. An experiment conducted in the Okanogan hills, about 8 miles from the British border, was of much interest. An attempt was there being made to raise this grass on rather poor upland soil without irrigation. In the more favored spots in the field it made some hay, and nowhere in the inclosure did it fail to yield twice as much pasturage as could ever be expected on the native range pastures of the vicinity. Small areas of this grass were seen in several other places in this region, but they were usually in pastures, and sometimes this grass was considered by the ranchers of little value on account of its not being able to withstand close grazing well. It appeared to the writer, however, that in many cases the difficulty resulted from the fact that the stock preferred this to the native grasses, and that the poor development was owing to its not having sufficient chance to make a growth.[a]

Nowhere in the Blue Mountains was any awnless brome grass seen until Izee was reached. There Mr. C. W. Bonham was experimenting in a small but very intelligent way, having about an acre of it growing in a corner of his garden, some with and some without irrigation. The experiment appeared very promising. Mr. Bonham reports that it is difficult to get the grass started, but he thinks that if sown at the proper time in a favorable year, and if irrigation were practiced, less difficulty would be experienced. He believes that it will make a good crop without irrigation when once a stand is secured. Some persons in Bear Valley are said to be preparing to put in large acreages of this grass next season. There is little doubt that it will succeed in many places in these mountains, where a much poorer quality of hay is now raised.[b]

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[a] At the experiment station at Pullman, Wash., awnless brome grass was less injured by close grazing than any other grass.—*W. J. S.*

[b] This grass yields a large crop of hay the second year from seed, but thereafter is adapted only to pasture purposes.—*W. J. S.*

GRAIN HAY.

By far the greatest quantity of roughage in all the country traversed outside of the irrigated areas is produced by the cereals sown in the ordinary way and cut when the grain is a little under the "dough" stage. Wheat, barley, and rye are especially the grains handled in this manner. In the Big Bend, in Washington, wheat furnishes almost the only hay in many places, the common practice being for the farmer to get his hay crop from the edges of his wheat fields. The wheat fields are "trimmed up" ten days or two weeks before harvesting begins. This trimming consists in cutting two or three swaths around the field while the straw is still green. Many wheat raisers secure their entire hay supply in this way. It is also a common practice when bearded barley is raised for the grain to sow a strip of wheat on the outside of the field, this being cut for hay.

This method of producing hay was more general on the north slope of the Blue Mountains than in any other section visited. Two factors contributed to the importance of the grain hay crop here, this year at least. In the first place, the past season was very dry, and the wheat crop consequently was very poor. On this account many fields were cut for hay instead of grain when it became evident that the yield would be small and poor at best. In the second place, being on the border of the area where a demand exists for winter feed for stock, wheat hay is nearly as paying a crop as the wheat itself.

Wheat straw is largely made use of here as a winter ration, especially for cattle. The stockman usually buys a field of straw and stubble, and winters his cattle very often with no other feed. This is better than the short range of the present day, but the stock usually come out of the winter in very poor condition. This method is a decided advantage to the wheat and hay grower, for, in addition to the ready cash, the land is improved by having the cattle upon it during the winter season.

Rye is a very important hay crop all through the region, and it is especially good on the sandy and poor soils along the Columbia and Snake River bottoms and portions of the Eureka flats, as well as on better soil. It is by far the most productive sandy-land crop, but is a rather exhausting one when the grain is allowed to mature. It appears to be the leading hay crop in all new communities, and is very extensively grown in the Blue Mountains, where especially good crops were seen in the vicinity of Ukiah and Izee. At the latter place it was estimated that more hay was derived from this source than from all others combined.

Of the grain crops sown primarily for hay, the awnless form of barley is probably the one that is considered best. This is grown largely in the wheat regions of Washington and in the Blue and the

Warner mountains, as well as in the Okanogan region and the irrigated communities of Ellensburg, North Yakima, and Lovelock, Nev. It is a common practice in the irrigated localities, when alfalfa fields have become thin owing to the length of their establishment, lack of care, overirrigation, or accumulation of alkali, to sow barley or wheat, either in drills or broadcast, early in the spring. This answers several beneficial purposes. The first crop of hay cut is greatly increased, the fields are in much better tilth, and a more perfect soil cover is secured early in the season, preventing a rapid evaporation from the soil during the spring and consequently decreasing the soluble salt content of the surface layers. It is said that this crop does not act injuriously on the alfalfa. It is a common practice also to scatter alfalfa seed in the meadows at the same time. This kind of a mixture makes excellent hay, and nearly doubles the quantity secured at the first cutting.

CHEAT.

Cheat[a] and grain (wheat, barley, and rye) are the main hay crops in the Blue Mountains of Oregon. The majority of the ranchers spoken with consider cheat superior to grain hay as feed for cattle and sheep. A few fields were seen in Washington, but it is not by any means so common there. It is not considered as good feed as timothy and redtop, but it makes a better yield on higher and drier areas than these crops. Nearly all ranchers in the Blue Mountains make a distinction between cultivated cheat and what they call wild cheat, which is described as the short-awned brome (*Bromus marginatus*) in the publications of the United States Department of Agriculture.

ROOT CROPS.

Some sheep men on the north slope of the Blue Mountains are beginning to raise considerable quantities of mangel-wurzels, beets, and carrots for the winter feeding of sheep. Messrs. J. E. Smith & Sons, who have the largest sheep interests in this area, report good success in their experiments in this direction. They are obliged at the present time to feed their sheep thirty to fifty days, as compared with ten days or two weeks years ago, when there was more open range. Thus far they have produced crops of this nature for only a limited number of their flocks, and these are fed mainly during the lambing season. The roots are chopped with a machine and fed with no further preparation. They consider these crops very profitable for this purpose. It is quite probable that ruta-bagas could be profitably added to this list.

[a] The species grown here appears to belong to *Bromus racemosus* rather than *Bromus secalinus*, under which name it is handled by seedsmen.

NATIVE HAY CROPS.

Wild wheat (*Elymus triticoides*).—This is without doubt the most important native hay plant of the region. It is known locally as bluejoint. Attention was called to this crop last year, but its importance was still more impressed upon the writer this year. In early days this was the main hay crop in the vicinity of Lovelock, and the name "Bib Meadows" is said to have originated from the extensive areas of hay land along the lower course of the Humboldt River where this was the principal species. Wild wheat was not met with on our route in any great quantities until we approached the Great Basin slope of the Blue Mountains, except in one locality on the Okanogan bottoms, where there was a large area of the white, or densely glaucous, form, which was so abundant at Quinn River Crossing, near Winnemucca, last year. At Izee, on the South Fork of the John Day River, it appeared to be of considerable importance in both hay and pasture land. Its best development, however, appears to be in the stiff, rather poorly drained, heavy, nonalkaline soils of the Great Basin bottoms. Here it grows out to the edges of the sagebrush areas, and often occurs in small quantities scattered for some distance into these areas, so that when they are irrigated, as is often the case, this grass springs up and extends with surprising rapidity, being spread, doubtless, to some extent by seeds, but more especially by its creeping rootstocks.

In the Lovelock region at the present time it is considered a weed, on account of the persistence with which it remains and spreads in cultivated fields. When lands are being brought under control it is very common to find areas of this grass scattered through the fields for some time, and it is almost invariably found along the irrigation ditches, where it serves the useful purpose of holding the embankments.

Bunch bluegrass (*Poa lævigata*).—Next in importance to the wild wheat is the bunch bluegrass, which is sometimes known as wild redtop. In the desert basins thousands of tons of this hay are cut each year. It grows in somewhat similar situations to the wild wheat, though usually on higher ground, and it appears to be able to withstand a greater amount of drought. Its habit of early maturing renders it of extreme importance in the Great Basin region. Often the only moisture which meadows obtain is from spring flooding, and this plant appears to be able to mature a fairly good crop of hay under these conditions. The most extensive areas of this grass were seen in the Catlow and Guano valleys and in the Deep Hole region on the edge of the Smoke Creek desert.

Giant rye grass (*Elymus condensatus*).—In all localities visited this is an important forage grass, but it is in the Great Basin that it attains its greatest importance as a hay crop. If cut when in bloom it makes fairly good hay, but if left standing longer than this it becomes very hard and woody.

Sprangle top (*Scolochloa festucacea*).—As stated in last year's report, the importance of this plant as a forage crop is surprising. Its distribution appears to be very local. The only place in this region where the writer has seen the plant is in Harney Valley, and there only in the vicinity of Malheur Lake, where it was fully reported upon last year, and along the Dunder and Blitzen River, where it was just as important as on the islands of Silvies River. Large quantities of hay were made of it this year on some of the "P" ranches.

Miscellaneous forage plants.—A very large part of the native hay throughout this region is obtained from the sedges and rushes, mixed with more or less of the native clovers, of which *Trifolium involucratum* and *T. microcephalum* are the most important on the lower areas and *T. beckwithii* in the mountains. *Trifolium cyathiferum* should also be mentioned as being of much value. Of the sedges, *Carex utriculata*, *C. lanuginosa*, *C. tenella*, *C. nebraskensis*, and *C. douglasii* provide the greatest quantity of feed and are of importance in the order named. They produce hay of less value than the grasses and clovers, but are much superior to the rushes, which are represented mainly by *Juncus balticus*, *Eleocharis palustris*, *Scirpus campestris*, *S. americanus*, and the tule (*S. lacustris*). Mention has been made of the extraordinary area of *Eleocharis palustris* in the Grand Coulee. Another equally striking illustration of the development of the *Juncus balticus*, also known as wire grass, came under observation along Crab Creek in Washington. Here it has been the practice for years to flood the meadows for a month or two after the hay crop has been removed for the purpose of attracting wild ducks, which are fed and systematically hunted during the open season, with the result that the meadows have grown up to almost pure *Juncus balticus*. This species almost invariably occurred in greater or less quantity in all meadows where timothy and redtop have been established without cultivation, more especially where the water is not under good control and is allowed to remain on the ground for long periods.

RECLAMATION OF SWAMP LANDS.

There were two regions on the route followed where gigantic operations were in progress for the drainage of swamp lands along streams which have a slight fall and are without any defined channels. The undertaking which came under direct observation was that inaugurated and carried on by the French-Glenn Live Stock Company along the Dunder and Blitzen River in eastern Oregon. This stream receives the drainage of a large portion of the western slope of Steins Mountains and empties into Malheur Lake. Both the upper and lower courses have well-defined channels, but the middle course is a swamp, where the water spreads over the bottoms and covers an area 8 to 10 miles in width by 12 to 15 miles in length. The region is now a huge tule swamp, where there is much feed around the edges, and cattle even work their way out into the swamp long distances; but it is during winter, when the ice is able to bear the cattle up, that the greatest amount of benefit is derived from it. At the present time the returns from the swamp are small. Besides this feature of small returns, the losses in the spring are very heavy. Cattle are usually so weak at this time of the year that when the ice begins to give way, they mire in large numbers and have not the strength to wade out.

The intention at present is first to cut a channel for the river, and then construct laterals as occasion demands for the purpose of draining the area. When this is accomplished it will be necessary to devise a method of irrigating this drained land properly. The construction is so planned that the channel cut for the river will unite with a large irrigating ditch covering a sagebrush flat. The water is simply turned on this sagebrush land at present, and what may is allowed to develop. Later this area will no doubt become a valuable alfalfa meadow and be irrigated systematically from the drainage waters derived from the swamp.

When this swamp, which is to a large extent a mass of peat, has been placed under control, the best crops to grow there will have to be selected. There is little doubt that the most profitable will be forage crops. The behavior of timothy and redtop all through the region under little or no cultivation makes it quite certain that these grasses will find an important place in the crops grown here in the future.

Similar areas have already been successfully drained along Pitt River, in Modoc County, Cal. Here the tule swamp lands are proving exceedingly well adapted to alfalfa growing. It is stated on good authority that some of the best alfalfa lands in the county are situated on these tule swamps.

The land in these swamps is, of course, exceedingly fertile, the drainage slight, and the waters different from those usually found in this region. They are not particularly alkaline, but are very highly colored with dead herbage, as is the case in some of the swamp lands in the Southern States.

The drainage of these areas, although a big undertaking, is only a portion of the difficulty involved in their handling. The method of managing them after they are drained and the crops best suited to them are problems which will require much careful investigation.

NEEDS OF THE REGION.

On account of such diversity of conditions it will be necessary to consider certain divisions of the territory more or less separately.

The greatest need of the Washington region, aside from the Okanogan River drainage area, is summer feed. As stated, this is principally a sheep region, where the animals are pastured the greater part of the year on the desert mesas of the Big Bend and contiguous regions in the winter and in the mountains for about three and one-half months during summer. The need of having animals in good condition in the fall, both for market and for entering the winter, and the necessity of an abundance of green feed for the best development of the lambs render these limited highland summer pastures of great importance to the sheep grower. On the other hand, winter feed is more abundant; for the deserts are extensive, and the irrigated hay lands, such as those of the North Yakima and Ellensburg regions, are producing more hay every year. For years past such communities have been shipping hay in large quantities to Coast points; in other words, they produce more hay than they can feed at home. For the greatest economy it is evident that the effort should be to increase summer feed so that enough stock can be summered in the region to consume the winter feed at home, thus saving transportation on raw material.

It was considerations of this kind that led Messrs. Benson and Babcock to offer to cooperate with the Department of Agriculture for the purpose of determining what could be done to increase the summer feed in the Wenatchee Mountains, in which they are interested.

Messrs. F. E. Benson and W. H. Babcock have come into possession of a large body of railroad land in the Big Bend at Trinidad, and a similar but smaller area in the Wenatchee Mountains southwest of Wenatchee. Their purpose has been to organize a sheep ranch on a sound basis, having definitely provided both summer and winter feed on lands which they control either by title or rental, instead of depending upon the open range for the larger part of both seasons' feed and being compelled to go out of business sooner or later, as is the case with so many of the stockmen in the West. The recognition of their need of more and better summer feed, which is the need of the region in general, induced them to offer to cooperate with the Department of Agriculture in experiments to improve the forage conditions of the summer grazing grounds by donating the use of an entire section of fenced land wherein experiments could be conducted. This offer has been accepted by the Department, and experiments have been begun under the direction of the Agrostologist. The objects of these investigations will be the introduction of forage plants which will increase the feed on highland pastures; a study of the effect of systematic grazing as compared with present methods, and of seeding at different seasons of the year, both with and without cultivation; a study of local meteorological conditions as affecting the growth of forage plants; a study of the native vegetation in its relation to the stock industry, and such other problems as may present themselves during the prosecution of the investigations.

The land set aside for the experiments is well adapted to this purpose. Being located in a typical grazing area and having been excessively pastured for a number of years, any advantage gained by treatment will point to methods of renovating denuded ranges. The land is described in the Government surveys as Sec. 23, T. 20 N., R. 20 E, and is locally known as the Babcock headquarters section, on account of the corrals located there. It has an altitude of approximately 5,000 feet. The region was gone over rather hurriedly in June. At this time there was no feed. Although the snow was still lying on the ground in deep drifts, the tract had already been pastured this season, for at that time none of the land was inclosed. Mr. J. S. Cotton, who has been placed in immediate charge of the work, reports that grasses have been nearly exterminated over a large part of the tract. The section, being located on the line of travel to and from the high mountains, has been grazed twice each season, in June and October, for a number of years. The soil is badly packed and cut by the flocks of sheep which have tramped over the ground while it was still wet from melting snows. In many places the soil has begun to wash badly.

While this is rather an extreme case of denudation, it nevertheless represents the exact condition of much of the range country at the present time, and shows what much more of it will become shortly if present methods are pursued. Any success in reestablishing the grass cover will be extremely important for all highland pasture regions.

Mr. Benson most aptly expresses the necessity for this work, as well as the needs of the region in general, in a letter to the Agrostologist, as follows:

> The shortening of summer pasture by forest reserve regulations and the overgrazing by sheep of the remaining pastures, coupled with the greatly increasing alfalfa production in the irrigated valleys to supplement the winter ranges, make the summer range more and more disproportionate to the winter range, until the important question now is, "How much stock can you carry through the summer?" and not what it has heretofore been in this country, "How are you fixed for hay? And how much stock can you winter?" Therefore it becomes very important to know what grasses or forage plants will do the best and yield the greatest amount of good pasture.

In the Blue and the Warner mountains the main problem is one of hay production. The winters here are more severe and stock must be fed for longer periods each year. Of course, the summer feed is also very short at times on account of the thousands of sheep which summer in these mountains. But the communities established here have managed in a measure to reserve some feed for themselves by establishing "dead lines" against sheep and by maintaining them at times with force.

Several of these communities are developing the dairy industry quite rapidly, and already Camas Prairie butter is of some importance in the local markets. The necessity of good pastures and hay crops for the proper development of this industry is obvious.

While much has been done by the Department of Agriculture and the State experiment stations in the development of the forage resources of the West, very little attention has been given in this country to experiments in this line in the mountains. The peculiar conditions existing in these mountain settlements render the necessity for new hay and pasture plants particularly pressing. In many localities the ranchers and farmers are already experimenting on their own account and will determine in time, by a laborious and expensive process, what could very properly be determined at public expense. The difficulties encountered by these farmers are enhanced by the practice, common with certain seedsmen, of foisting upon the farmer, under a new and frequently high-sounding name, some worthless weed, or some plant of very limited usefulness. To illustrate: Some people have invested considerable money in the seed of a supposedly new forage crop under the name of "Billion-dollar grass," and were surprised when they were informed that it was an annual grass, and much chagrined when they got no results on dry land without irrigation, or when with irrigation on rich alluvial deposits they secured only a scattering growth of the common barnyard grass—a common weed all over the United States.

As stated elsewhere, grain, hay, and cheat are the main hay crops in these mountain settlements at present. These certainly can be improved upon. Some timothy and redtop are grown, and awnless brome is being gradually introduced. It appears to the writer that some work of an experimental nature would be very desirable in these mountain communities. A series of experiments conducted here for about three years with a carefully selected list of about fifty forage plants would demonstrate what forage crops could be grown to advantage at these high altitudes and would be of inestimable benefit to the pioneers who are building homes here.

In the numerous desert basins where water available for irrigation can be secured for only a short period, or, in other words, where the meadows can be irrigated in late winter only and where now the sedges and rushes are the main hay crops, the need of a perennial hay plant that will mature early is evident. The native plant, bunch bluegrass (*Poa lævigata*), seems the most promising for this purpose. As previously stated, this furnishes much hay at the present time and appears well adapted to this form of treatment. The characteristics which make this a valuable grass are discussed elsewhere and need not be repeated here. It is possible that some annual crops might be found to be profitable here, but it must be considered that the returns per acre, which are very small, make the profits from the cultivation of large areas for annual crops rather problematical.

In practically all of the irrigated districts where alfalfa is raised the settlers were nearly all looking for some strain of alfalfa which will thrive with less water than the common stock. The introduction of Turkestan seed a few years ago having resulted indifferently, attention has recently been attracted to "dry-land" alfalfa, concerning which much has appeared in periodicals during the past year. The growing tendency in all the irrigated districts to bring more land under cultivation than can be properly irrigated has emphasized the demand for a crop that may be grown with little or no irrigation in arid climates. Correlated with a scarcity of water is the accumulation of alkali, which calls for the development of strains resistant thereto.

The matters just mentioned, together with the determination of the best method of handling the swamp lands and the best hay crops to grow upon them, appear to be the most important forage problems of the region.

PLANTS INJURIOUS TO STOCK.

But little can be added to what was said last year regarding poisonous plants in pastures and meadows. In all swampy places, especially in the vicinity of springs, there occur more or less wild parsnips (*Cicuta vagans*). This and larkspur (*Delphinium scopulorum*) are dreaded by ranchers in the spring of the year, especially in the Great Basin region.

The slender fescues (*Festuca microstachya* and *F. octoflora*) are said to cause injury about the time that the seed is ripening. The injury is done by the seed working its way into the walls of the animal's stomach. This is reported on what is, without doubt, reliable testimony from two observers, both of whom were in position to form opinions from post-mortem examinations. Mechanical injuries of this nature are not at all uncommon, the best-known examples being those caused by squirrel-tail grass (*Hordeum jubatum*), the awns of which work their way into the lining membranes of the mouth, and needle grass (*Stipa* spp.), the seed and awns of which work their way into the wool and flesh of the sheep. To these might be added the triple-awned grass (*Aristida americana*) and six weeks' grass (*Bouteloua aristoides*) of the Southwest, which are dangerous to sheep at certain seasons, the awned seeds in the first instance and the spikelets in the second case acting in the same way as the seed of the needle grasses.

WEEDS OF MEADOWS AND PASTURES.

The ordinary annual weeds of the farm can not combat with alfalfa as handled in the irrigated West. Wild lettuce, which is a serious pest in parts of the wheat region, soon disappears from the field when properly handled in alfalfa culture. The weeds which thrive in alfalfa are those which propagate by running rootstocks. Two such grasses, salt grass and wild wheat (*Elymus triticoides*), are at times quite conspicuous and much dreaded in the Lovelock district. It is a very common thing here to see patches of these two grasses, but more especially the former, making their appearance in alfalfa meadows and spreading with surprising rapidity. The salt grass is by far the most troublesome, because it finds in these soils congenial conditions, which at the same time are detrimental to the crop. Through cultivation, application of manure, and reseeding with alfalfa, or even a temporary grain-hay crop, which gives a soil cover, this weed can be kept in check. Although the salt grass is looked upon here as a weed, it would seem that the real trouble is with the soil and not so much with the weedy tendency of the grass. If the soluble salt content of the soil is kept down by the methods already enumerated, salt grass will not find congenial conditions. The difficulty seems to be simply one of alkali and not of weeds. The wild wheat, or blue joint, on the other hand, does not thrive in particularly alkaline soil, and is really a plant that can be handled as easily as the western wheat grass (*Agropyron occidentale*) on the prairies of the Great Plains.

Blue flag (*Iris missouriensis*, Pl. X, fig. 2) is a very serious pest in moist pastures. In portions of the Wenas Valley where pastures were overstocked there was a complete soil cover of this weed in many native meadows. In many places where it develops to this extent it would be hazardous to break the soil, for fear that it might be washed away. However, mowing would do much toward getting rid of blue flag, and an attempt should be made at every favorable opportunity to establish a more complete crop of timothy and redtop in such localities.

The dandelion is also a very serious pest in native meadows and pastures which have been in use a long time in northwestern Nevada and northeastern California. It has spread very rapidly of late in many sections of the West where little or no cultivation is practiced. It has been introduced doubtless with timothy and redtop, which are largely employed throughout the region to supplement and supplant the native vegetation. It is all the more serious because it is introduced in places where, on account of the location of the arable land in narrow strips along rivulets, its destruction by cultivation, which is the only known method of eradicating it, is impracticable or, in certain localities, hazardous, on account of danger of erosion when the sod is broken up.

The native plants which become weedy in the more humid localities under conditions of overstocking have been discussed elsewhere.

DISEASES INJURIOUS TO FORAGE CROPS.

All of the more important diseases of forage plants observed were caused by various species of smuts. This class of parasitic fungi injures more than one would suppose the development of native economic plants. While this is true, so little is known of the life history of these species that no suggestion can be made regarding their control further than to state that the spread of those species which attack hay plants could probably be checked by careful mowing and the removal of hay from affected fields before the grasses head out. The acreages are so large and the returns from them so small, however, that it is doubtful whether any method which would be successful would be financially justifiable.

Ustilago hypodites.—In portions of the Great Basin, as well as in the Okanogan region in Washington, a very large amount of damage is done by this smut. It attacks both giant rye grass and salt grass, transforming the undeveloped portions of the plants within the upper leaf sheaths into a black powdery mass. It was especially destructive in the Quinn River and Alvord regions in Nevada and Oregon last year, and again this year in Surprise Valley, California, and at Lovelock, Nev., on both hosts.

Ustilago scolochloa.—This smut attacks the valuable sprangle top (*Scolochloa festucacea*). Its black, sooty spores break through the epidermis on the upper side of the leaves, stunt the growth of all the leaves, prevent the upper ones from opening, and entirely destroy the seed. At the "sod house" on the lower course of the Dunder and Blitzen River some meadows, in which one-half to two-thirds of the vegetation consisted of this grass, had fully one-half of the plants smutted.

Tilletia fusca.—The hosts of this smut, the slender fescues (*Festuca octoflora* and *F. microstachya*), are annual plants, depending entirely upon seed for their reproduction. The fungus in this case transforms the seed into a black horn-like structure, filled with a compact black mass of spores, entirely destroying it in practically the same manner as the bunt destroys the kernel of wheat. Nothing short of the excellent seed habits possessed by these grasses would enable them to thrive at all, for there are many localities in eastern Washington where upward of three-fourths of the plants had all their seed destroyed. Reference is especially made to the region about 25 miles north of Prosser, where the above statement would be no exaggeration. At the same time another species of smut (*Ustilago mulfordina*) did some injury also.

Ustilago bromivora.—The seed production of the valuable short-awned brome grass (*Bromus marginatus*), as well as that of the closely related cheat, is very materially reduced by this smut. The injury to the form of *Bromus secalinus* which has escaped from cultivation and grows as a weed seems to be much more pronounced than that of the cultivated form, which, as previously stated, corresponds more closely to *Bromus racemosus*.

Ustilago striæformis.—This common disease did more injury to timothy in Jess Valley, California, than the writer has ever observed elsewhere. It appeared to be confined here to well-drained areas, which were abundantly supplied by seepage from ditches, rather than to the more poorly drained or the drier portions of the meadows.

SUMMARY AND SUGGESTIONS.

NEEDS OF THE REGION.

The sheep industry is more in need of summer pasture than anything else. This is accounted for by the settling up of mountain meadows, the development of alfalfa regions, and the withdrawal of land from the public domain for timber reserves.

The mountain communities of the Blue and the Warner mountains need to have determined what hay and pasture crops can be grown in these highland regions to best advantage.

In the desert basins, where water for irrigation can be obtained for only a very short time, there is need of an early maturing perennial grass.

The alfalfa growers call for two new varieties of alfalfa—one which will survive with less water than the common form, and one which will resist the effect of soluble salts in the soil. The development of these two strains can be secured only through careful experimentation.

ABUSES.

The whole subject of abuses can be summed up under the head of overstocking, but there appear to be two practices which need special attention. At present stock are allowed on high mountain pastures too late in the spring. They should be taken from these pastures as soon as frost begins to disappear, so that the sod will not be injured. Even the carefully handled tame pastures of the East will not stand grazing at this period.

The second abuse of the range to which the writer wishes to call attention is the "cayuse nuisance." With the decline in the price of horses about 1894 these animals were allowed to run wild, with practically no attention, many herds not even being rounded up and branded. Under these conditions, of course, the horses multiplied and deteriorated rapidly on account of inbreeding, resulting in the overstocking of the ranges with animals which were all but worthless. It was this condition which led the legislature of Nevada, in 1897, to enact a law providing for the destruction of these "unbranded wild" animals. During the past three years thousands of these horses have been shipped out of the country (Pl. VIII, fig. 2), thereby relieving the situation very much; but there are still altogether too many of them on the ranges. The quantity of range feed consumed by a good animal is no more than that eaten by one of these almost worthless "cayuses."

NATIVE GRASSES WORTHY OF CULTIVATION.

Wild wheat (*Elymus triticoides*).—It appears to the writer that wild wheat is worthy of extended trial under cultivation. It is promising in stiff soils where there is considerable moisture up to the middle of June. It is also of some promise for holding clay banks which wash badly in the more humid regions.

Bunch bluegrass (*Poa lævigata*).—The large quantity of excellent hay made of this grass all through the region traversed, as well as its good seed habits, make it a promising plant for cultivation.

Short-awned brome (*Bromus marginatus*).—In the highland region there is no native plant that gives more promise than this. At the present time large quantities of it are common all through the mountains in poorly cultivated fields. In Fox Valley several fields of cheat were seen where one-half of the yield consisted of this native species. When cut in season the quality is good, and its seed habits are excellent, resembling those of rescue grass more closely than any of the cultivated species of this genus.

Mountain rye grass (*Elymus glaucus*).—Observations in mountainous regions tend to indicate that this species is of some promise. Several limited areas in the Blue and the Warner mountains suggest that it might be made use of in cultivation. A careful examination into the conditions in the Rocky Mountains, especially in the vicinity of Summit, Mont., strongly confirms this opinion.

Bunch wheat grass (*Agropyron spicatum inerme*).—The importance of this grass on the native ranges and the successful attempts which have already been made to grow it leave little doubt as to its value for cultivation, although the hay made from it is rather hard and wiry. Its value as a pasture plant may be questioned on account of its inability to withstand trampling. Some ranchers stoutly maintain that when once closely grazed it will not recover in a reasonable length of time.

Giant rye grass (*Elymus condensatus*).—The excellent seed habits of giant rye grass, its large yield, and its ability to thrive on stiff, hardpan soil along with salt grass render it of considerable promise for cultivation, especially in the Great Basin region.

INDEX OF GRASSES AND FORAGE PLANTS.

DESCRIPTION OF PLATES.

Plate I. (Frontispiece.) Map of Pacific Northwest, showing route traveled.

II. Fig. 1.—A good summer sheep range in the Blue Mountains of Oregon. In the foreground are willows, alders, and the service berry. On the hillside to the left is seen *Purshia tridentata*, with a liberal supply of the common grasses. Fig. 2.—A desert range in northwestern Nevada. In the foreground appears the "sleek" desert of Black Rock, with the Granite Mountains in the background. The white streak at the base of the mountains is caused by a mirage, and is at least 2 miles distant.

III. Fig. 1.—Good scab-land range near Trinidad, Wash. Black sage, bunch wheat grass, a little sheep fescue, and Sandberg's bluegrass constitute the main vegetation. Fig. 2.—Desert range near Mirage, Nev. Vegetation almost pure *Atriplex confertifolia*.

IV. Fig. 1.—Typical range view in the Okanogan Hills, Washington. Sheep fescue, bunch wheat grass, Nevada bluegrass, Wheeler's bluegrass, and giant rye grass are shown. Fig. 2.—Typical ranch in the Blue Mountains of Oregon.

V. Fig. 1.—A sheep range on the north slope of the Blue Mountains. The native vegetation here has been largely replaced by cheat. Fig. 2.—A denuded mountain meadow on the north slope of the Blue Mountains.

VI. Fig. 1.—Corraling ground in the Warner Mountains of California. In the center of the foreground is shown the condition of Indian currant (*Symphoricarpos oreophilus*). Fig. 2.—Winter range in northwestern Nevada. White sage appears on the lower area in foreground, while *Atriplex confertifolia* and bud sage are seen at the base of the hill and red sage on the higher slopes.

VII. Fig. 1.—Timothy and redtop on uncultivated land, Warner Mountains, California. Fig. 2.—*Bromus inermis*, irrrigated, near the mouth of the Okanogan River, Washington.

VIII. Fig. 1.—A narrow valley along Silvies River, Blue Mountains, Oregon. Timothy, redtop, native grasses, clovers, and sedges are cut here, usually on uncultivated ground, with some alfalfa on the better drained areas. Fig. 2.—A horse round-up, showing the cayuse, the menace of a large part of the range country.

IX. Fig. 1.—An overpastured highland meadow in the Washington wheat region. Yarrow is the most conspicuous plant. Fig. 2.—An overpastured lowland meadow, Wenas Valley, Washington. *Iris missouriensis* has taken possession.

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FIG. 1.—A GOOD SUMMER SHEEP RANGE IN THE BLUE MOUNTAINS OF OREGON.

FIG. 2.—A DESERT RANGE IN NORTHWESTERN NEVADA.

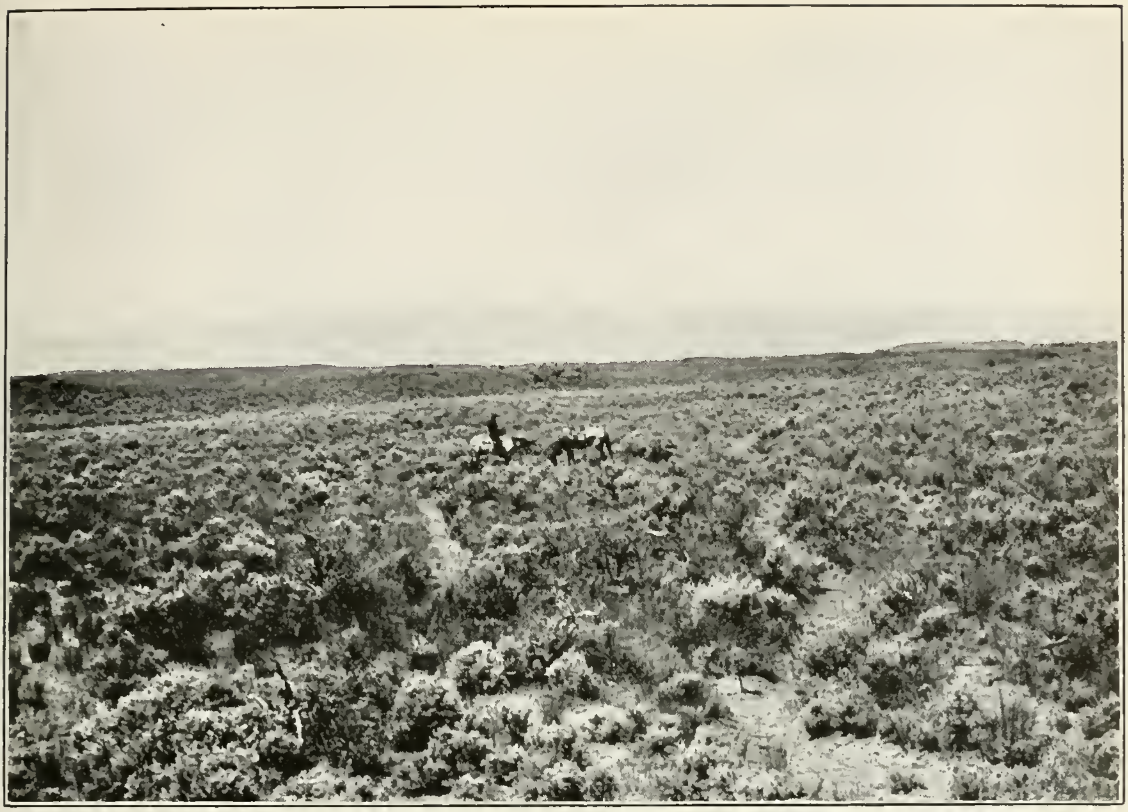

FIG. 1.—GOOD SCAB LAND RANGE NEAR TRINIDAD, WASH.

FIG. 2.—DESERT RANGE NEAR MIRAGE, NEV.

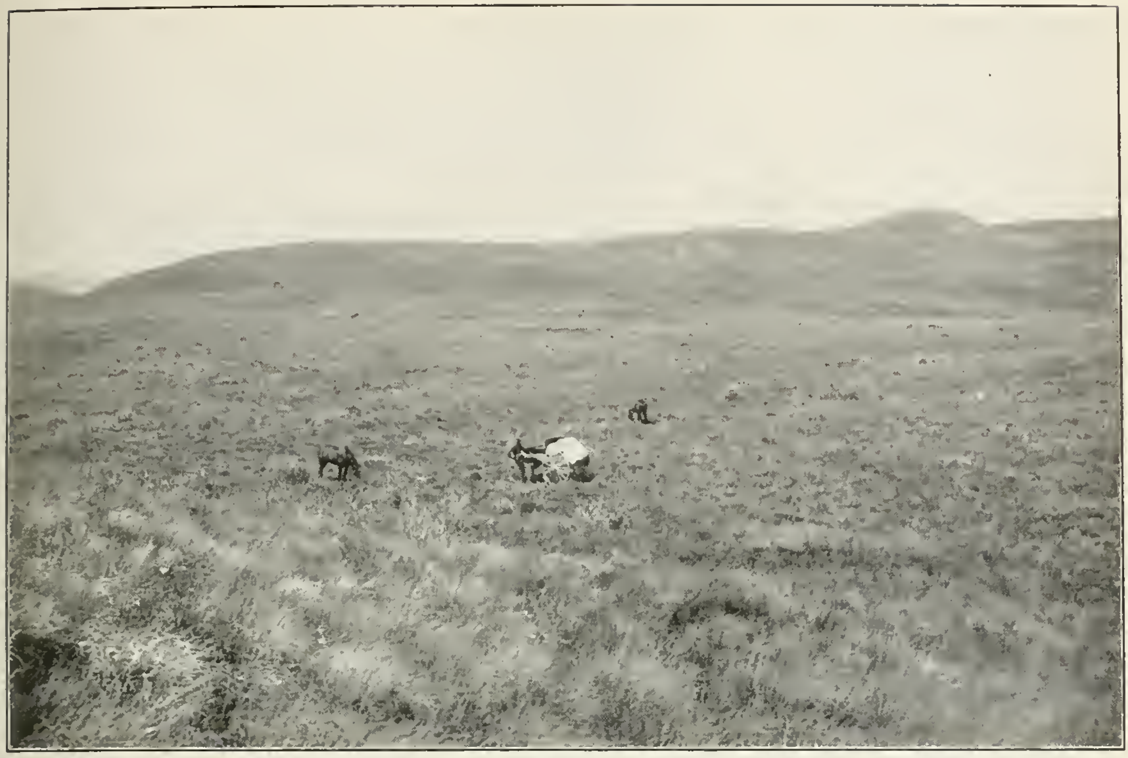

FIG. 1.—TYPICAL RANGE VIEW IN THE OKANOGAN HILLS, WASHINGTON.

FIG. 2.—TYPICAL RANCH IN THE BLUE MOUNTAINS OF OREGON.

FIG. 1.—A SHEEP RANGE ON THE NORTH SLOPE OF THE BLUE MOUNTAINS.

FIG. 2.—A DENUDED MOUNTAIN MEADOW ON THE NORTH SLOPE OF THE BLUE MOUNTAINS.

FIG. 1.—CORRALLING GROUND IN THE WARNER MOUNTAINS OF CALIFORNIA.

FIG. 2.—WINTER RANGE IN NORTHWESTERN NEVADA.

FIG. 1.—TIMOTHY AND REDTOP ON UNCULTIVATED LAND, WARNER MOUNTAINS, CALIFORNIA.

FIG. 2.—BROMUS INERMIS, IRRIGATED, NEAR THE MOUTH OF THE OKANOGAN RIVER, WASHINGTON.

FIG. 1.—A NARROW VALLEY ALONG SILVIES RIVER, BLUE MOUNTAINS, OREGON.

FIG. 2.—A HORSE ROUND-UP, SHOWING THE CAYUSE, THE MENACE OF A LARGE PART OF THE RANGE COUNTRY.

FIG. 1.—AN OVERPASTURED HIGHLAND MEADOW IN THE WASHINGTON WHEAT REGION.

FIG. 2.—AN OVERPASTURED LOWLAND MEADOW, WENAS VALLEY, WASHINGTON.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 39.

B. T. GALLOWAY, *Chief of Bureau.*

THE PROPAGATION OF THE EASTER LILY FROM SEED.

BY

GEORGE W. OLIVER, EXPERT.

SEED AND PLANT INTRODUCTION AND DISTRIBUTION.

ISSUED JUNE 24, 1903.

WASHINGTON:
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1903.

BULLETINS OF THE BUREAU OF PLANT INDUSTRY.

The Bureau of Plant Industry, which was organized July 1, 1901, includes Vegetable, Pathological, and Physiological Investigations, Botanical Investigations and Experiments, Grass and Forage Plant Investigations, Pomological Investigations, and Experimental Gardens and Grounds, all of which were formerly separate Divisions, and also Seed and Plant Introduction and Distribution, the Arlington Experimental Farm, Tea Culture Investigations, and Domestic Sugar Investigations.

Beginning with the date of organization of the Bureau, the several series of bulletins of the various Divisions were discontinued, and all are now published as one series of the Bureau. A list of the bulletins issued in the present series follows.

Attention is directed to the fact "that the serial, scientific, and technical publications of the United States Department of Agriculture are not for general distribution. All copies not required for official use are by law turned over to the Superintendent of Documents, who is empowered to sell them at cost." All applications for such publications should, therefore, be made to The Superintendent of Documents, Union Building, Washington, D. C.

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[Continued on p. 3 of cover.]

BUREAU OF PLANT INDUSTRY.

BEVERLY T. GALLOWAY, *Chief of Bureau.*

SEED AND PLANT INTRODUCTION AND DISTRIBUTION.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., May 4, 1903.

Sir: I have the honor to transmit herewith a paper entitled "The Propagation of the Easter Lily from Seed," and respectfully recommend that it be published as No. 39 of the series of Bulletins of this Bureau.

This paper was prepared by Mr. George W. Oliver, Expert, and was submitted for publication by the Botanist in Charge of Seed and Plant Introduction and Distribution.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

CONTENTS.

ILLUSTRATIONS.

THE PROPAGATION OF THE EASTER LILY FROM SEED.

THE BERMUDA LILY.

In the United States *Lilium harrisii* came into prominence nearly twenty-five years ago, a few bulbs being brought from the Bermudas about that time. These were propagated and their superiority for early forcing demonstrated. Elwes, in his monograph of the genus Lilium, mentions the introduction of the same variety from Japan into Great Britain at about the same period. He also states that the *Lilium longiflorum* was introduced into Great Britain by the Royal Horticultural Society in 1819. *Lilium harrisii* has the distinction of coming into bloom much earlier than the true *L. longiflorum* with similar treatment. It is probably the type of *L. longiflorum* which is found farthest south in the region where that species is indigenous. This region comprises southern and central China, the Riu Kiu Islands, and south Japan.

From small beginnings a little more than twenty years ago, the Easter-lily industry has assumed vast proportions in recent years. In Bermuda more than 3,000,000 bulbs are exported annually to the United States. In Japan, at the present day, millions of bulbs are grown from seed each year, the demand being so large that enough can not be grown from vegetative reproduction. But, unfortunately, up to the present time there has been no selection from the seedlings. This is the reason why with each importation from Japan many bulbs are found which, when the plants begin to bloom, lack uniformity in size of stem, time of flowering, and other characteristics. It is reported that the Japanese department of agriculture has taken the matter in hand, with a view to inducing the growers to weed out inferior seedlings and propagate only from the best. It is owing principally to the decadence of the Bermuda crop that the demand for bulbs, chiefly of *L. longiflorum* from Japan, has increased so very markedly in recent years. In 1879 the value of the bulbs exported from that country was $2,500; in 1895, $40,000. In 1899, however, the figures jumped to $130,000, and the increase during the past three seasons has doubtless made corresponding strides.

VARIETIES OF LILIUM LONGIFLORUM FROM JAPAN.

The bulbs imported from Japan are chiefly *L. longiflorum*. Among them are several distinct varieties which differ from each other principally in the periods of blooming, but also in foliage, flowers, and general habit. Some have the leaves close together on the stem, the longest and broadest at the base, gradually shortening as the summit is reached. (See Pl. II, fig. 1.) Others have broad leaves, not so numerous as in the case of the plant just mentioned and with less difference in breadth and length between those at the base of the stem and those near the apex (Pl. II, figs. 2 and 3.) Some of the forms appear to be of a fixed type so far as scarcity of blooms is concerned. This is attributed to seedling stock raised from unselected parentage and the failure to breed continuously from the most desirable of the seedling plants. If this is the case, as there is good evidence to suppose, it is little wonder that the imported stock lacks uniformity in many of the most desirable characteristics.

Among the numerous forms there is one which shows great superiority over the others. In every respect it may be regarded as an ideal lily. It is said to have been found in a certain locality in Japan and named after the place where it was discovered. It is offered by two dealers under the names *L. longiflorum giganteum* and *L. longiflorum eximeum giganteum*. It is said to be a difficult subject to propagate vegetatively; consequently it is higher priced than any of the others. Some years ago when first sent to this country it was thought to be a natural hybrid between *L. longiflorum* and *L. brownii*. The leaves of this variety are not as numerous as in some varieties of *L. longiflorum*; they gradually taper from base to summit, but in this respect are not as pronounced as in some other forms. The stem for several inches above the base is of a blackish-brown color. The flowers are graceful in shape, the tube is short, and the diameter across the perianth is large. The texture of the flower is much firmer than that of any other cultivated lily, and the color is of a dazzling clear white. Either on the plant or in a cut state the flowers, by reason of their thick texture, last longer than those of any other form of *L. longiflorum*. With regard to the time it takes to force, it occupies a position in this respect midway between *L. longiflorum* and *L. harrisii*. Unfortunately, however, disease is quite as prevalent in this form as in others. Therefore, the propagation of the limited amount of stock available by scales, offsets, or division, and under the same conditions as those existing in the Bermudas will be accompanied with no better results than are found in the *L. harrisii* product of the island. A bright future for this plant is predicted, not only on its individual merits but also as a parent, both male and female, from which to raise new forms through crossing with other varieties of *L. longiflorum*.

In the greenhouses of the Department of Agriculture there are at present several combinations between this plant and the most approved forms of *L. harrisii*. The plants are still in the seedling stage, but they will be watched with very great interest to determine the results of careful cross fertilization with the other varieties. Although the plants are so small that 100 could easily be put inside of a thimble, they are expected to flower within seven months.

Some bulbs of this little-known variety which were planted out in the open during the autumn of 1901 along with other *L. longiflorum* and *L. harrisii* plants, to test their hardiness and blooming periods and also to learn of their adaptability to the soil of this section, showed that they were not only hardy, but that the blooming period was ten days in advance of the earliest of the *L. longiflorum*. The bulbs planted were small and when lifted, during the latter part of August, were found to have increased considerably in size, besides making several small bulbs at the bases of the stems. The soil used is composed of friable loam, having been under cultivation a long time, but no manure had been given within two years before planting. Two dry spells occurred during the period of growth and this retarded their development to some extent.

DETERIORATION OF THE BERMUDA AND JAPAN GROWN LILIES.

Owing to the frequent and constantly increasing number of complaints relative to the diseased condition of the Bermuda and Japan-grown Easter lilies, the growers of this country are confronted with a condition to which considerable attention has already been given with a view to mitigating the troubles with which they have to contend in forcing the bulbs into bloom. When it is considered that probably over 5,000,000 lily bulbs are forced into flower during the winter and spring months, it will be seen that the crop is of great value; but notwitstanding all that has been done, the experiences of the principal greenhouse men indicate that the profits are very much curtailed owing to the diseased condition of the plants.

This disease shows its presence by the leaves becoming more or less discolored and the shape of the leaf altered so as to appear twisted. The flowers also lack the usual form and substance and the whole plant is dwarfed. When in bloom, if it ever reaches that stage, the diseased plant does not bring one-fourth of the price obtainable for a healthy plant. During the past year complaints have been received from some of the largest growers that of their plants the bulbs of which were obtained from Japan and Bermuda from 20 to 60 per cent were diseased, and almost all of these were unsalable.

The causes of the diseased condition of the plants have been investigated by the best pathologists in this country and in Europe. Mr. A. F. Woods, Pathologist and Physiologist of the Bureau of Plant Industry, U. S. Department of Agriculture, issued a bulletin in 1897 giving the result of his investigations of the lily disease.[a] In this work the causes of the disease are discussed and remedies suggested. The florists of this country, however, who force the lilies have not the remedies in their own hands, as the disease is present in the bulbs before they are imported. In a later paper Mr. Woods has discussed the relation of nutrition to the health of plants, with special reference to *Lilium harrisii*.[b]

Lily growing on the Bermuda Islands is an exceedingly profitable industry. Practically all the land available for the production of bulbs is utilized for this purpose, and while the rotation of crops, together with the most approved methods of selection and cultivation, would undoubtedly be eventually a good policy for the growers to pursue, yet, except in the case of the more progressive growers, there is little likelihood of this being done, as it would materially decrease the revenue from lily farming for the time being. This will readily be understood when it is stated that an acre of lilies will bring from $1,000 to $2,000. Some growers on the islands who thoroughly appreciate the importance of careful methods are using small bulbs in preference to scales, and are selecting and fertilizing carefully, but they are heavily handicapped by the many small growers who cultivate their crops according to old methods; and in these cases there is no selection with a view to producing and perpetuating good types. Little manure is given. The methods of propagation are very faulty and they have not been changed since the beginning of the industry in the islands. For instance, in the growing of the bulbs for American markets the smaller sizes are planted in the fall and harvested in July, or before the bulbs have thoroughly ripened. In the process of handling, many of the immature scales drop from the bulbs. These are not thrown away, as they ought to be, but are carefully saved and planted with a view to raising small bulbs. These bulbs ultimately form a large part of the general crop.

As a result of some investigations made by the United States Department of Agriculture. it has been shown that by the use of seeds instead

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[a] Bulletin No. 14, Vegetable Physiology and Pathology, U. S. Department of Agriculture, 1897.

[b] Yearbook U. S. Department of Agriculture, 1901, pp. 155–176.

of scales larger bulbs can be secured in a much shorter time than can be produced by the scale method. If the general crop were raised from seeds there would be a saving of at least a year in the production of a marketable bulb. Moreover, it has been demonstrated that in this way plants can be grown which are entirely free from disease, and, most important of all, that the seedlings give an opportunity to select better types than exist at the present time.

RECENT EFFORTS TO CULTIVATE THE EASTER LILY IN THE UNITED STATES.

For some years efforts have been made to cultivate successfully the Easter lily in the Southeastern States. This work is of considerable value in showing future growers what to avoid, but it has so far not been demonstrated that the lily, with the methods used, can be grown to compete with the foreign product. Not only are the bulbs late in ripening, but when harvested they seldom show any increase in size over that at the time of planting. The cultivation of the lily in the Southern States has evidently been conducted with a view to producing bulbs which would ripen in July, or early enough to compete with the Bermuda-grown product. This result has not been accomplished, and with a continuance of the same cultural methods it is not likely to be. Furthermore, a practice which has undoubtedly contributed somewhat to this lack of success consists in using the stock as received from the Bermudas and Japan. It is admitted that in the Southeastern States the climate is not as favorable for the bulbs as it is in the countries mentioned; therefore, it follows that early planted bulbs starting into growth during the warm days of autumn and weakened by the cold spells of winter will fall an easy prey to the diseases present in the imported bulbs when planted. If success is to be attained in the future in producing bulbs of marketable size, it must be with different methods and along entirely different lines from those followed in the past.

It has been demonstrated by Mr. A. F. Woods, of the Bureau of Plant Industry, that bulbs of the Easter lily can be carried over a season in cold storage. Not only is this operation a success in itself, but it has resulted in showing that the bulbs are benefited very materially by this treatment, as it subjects them to a condition to a certain extent approaching that existing in Japan, the native country of the species, where the bulbs are heavily covered with snow during the resting period. This fact opens up new possibilities in the cultivation of the lily. Heretofore, bulbs have been planted in some parts of the South early in the fall, with the result that they sprouted considerably before cool weather set in. In fact, the growth made at a certain period was quite as far advanced as that in Bermuda at the same date; but the climatic and soil conditions being so different in the South from those prevailing in Bermuda, the results were more or less disastrous. The growth above ground, where the plant was not killed outright, was more or less injured by cold and other generally unfavorable conditions. During the period before coming into bloom, the plants rendered sickly during the winter often suffered severely from lack of moisture, resulting in poorly developed bulbs.

So far, practically nothing has been done in experimental work with a view to giving the bulbs the most favorable conditions to develop, leaving out of consideration altogether early ripening for forcing the following fall. It is the intention of the Department of Agriculture to work with this end in view, not only in the South but in the Middle and Northern States and also in the West.

A knowledge of the proper time to plant the bulbs in the various sections of the country in order to produce a bulb of maximum size in as short a time as possible but in a thoroughly ripe condition before being harvested is most important, and this knowledge is to be gained only by carefully conducted trials. Every florist who is interested should experiment in a small way to ascertain how the bulbs will succeed out of doors in his section of the country.

The soil problem does not present many difficulties beyond the selection of well-drained situations and a light, sandy loam, which can be kept sufficiently moist during the growing season to prevent the plants from receiving a check. Treatment should be accorded a portion of the bulbs similar to that found to succeed with bulbs of the other species of *Lilium*, such as *L. auratum*. This consists in placing in the vicinity of the bulb, moss or other material which will retain more moisture than the surrounding soil. During dry weather this is found to be an excellent provision for supplying the growing roots with moisture until a fresh supply is received from rains and until the roots penetrate deeply into the ground, so as to withstand dry spells. In trials of this nature the bulbs should be allowed to stay as long as possible in the ground after the tops decay. They should be harvested just before there is danger of their beginning growth for the following season, because any interference that tends to cause premature shriveling and decay of the thick roots near the base of the bulb, such as harvesting before natural ripening occurs, invariably occasions a shrinkage of the tissue of the outer scales and incidentally provides a ready means of ingress for fungi and bacteria to the tissue of the bulb through the ruptured tissue of the roots. This condition of premature decay, while the bulbs of the field are subjected to moisture, even for a short time, provides favorable harbors for mites, which, although their purpose at first may be merely to feed on the decaying tissues and act as scavengers, will ultimately injure what remains of the bulb by attacking the living tissues, rendering the bulb more susceptible to other maladies. Thus by a system of vegetative reproduction, the bulbs, even though they be in a healthy condition and free from disease of all kinds previous to lifting, may afford by careless harvesting a lodgment for various enemies and give opportunities favorable for disease year after year.

LINES OF INVESTIGATION CARRIED ON BY THE DEPARTMENT OF AGRICULTURE.

That the progress of the disease is accelerated through the present methods of handling and cultivation is shown by the fact that in the Bermudas there are private gardens in which the lily has been undisturbed for years where the plants grown show no trace of disease. The recent investigations by Mr. A. F. Woods show that the disease is due to several causes, and may be brought about by a weakened condition through improper harvesting, resulting in the attacks of mites, fungi, and bacteria. There is nothing to indicate just how long it would take to rid the plants of the disease by giving proper treatment in the Bermudas, but the easiest way out of the difficulty appears to be in raising and selecting stock plants not from scales, but from seeds, and in planting the bulbs within our own borders, where, if given the care which the crop demands, there is every reason to expect that the difficulty will be solved in the near future.

In a large number of seedlings at least 50 per cent can be counted upon to possess desirable characteristics, which will be shown the first year following that in which the seed is sown by the plants coming into flower. The remainder can, if it is thought necessary, be discarded and the good ones grown on for forcing, the size necessary for which will be attained the season following, or within two years from the time the seeds are sown. The very best of these seedlings, some of which will undoubtedly show superiority in several ways over the parents, can be retained for seed, and by keeping up the system of selection there will develop in a very few years strains from seed which will be superior to most of the plants placed upon the market at the present day.

In beginning the work of bulb growing in the United States along entirely new lines there seemed little probability of securing stock from the Bermudas or Japan for vegetative reproduction, which could be relied upon as absolutely free from disease. There are localities in the Bermudas where lilies are growing which appear to be quite healthy; there is, however, a danger of the bulbs being more or less contaminated, owing to the close proximity of the districts where the diseased bulbs are grown. Therefore recourse must be had to some method other than vegetative reproduction from foreign-grown bulbs.

The beginning of the experimental work along this line has been carried on with the utmost care. Several bulbs of the true *L. longiflorum* and its principal forms were secured. These bulbs showed no indications of the presence of the disease by the usual diagnosis. As the growth above ground developed, those plants which in any way showed signs of abnormal development were removed from the greenhouse and destroyed. A rigid process of selection was carried on up to the time the plants came into flower, with the result that at the blooming period the various groups were made up of fine specimens of the several types of *L. longiflorum*. These were *L. l. eximeum*, otherwise *L. harrisii*, *L. l. latifolium*, *L. l. multiflorum* and *L. l. eximeum giganteum*. Each group was kept separate from the others so that there should be no likelihood of accidental intercrossing. Those plants which were selected as seed bearers were emasculated while the anthers were still immature. In no case was a plant allowed to have a flower fertilized by its own pollen or even from that of other flowers on the same plant. In this way the chances are the greater that the resulting seedlings will show more vigor than if each flower had been self-pollinated, or if pollen had been transferred from one flower to others on the same plant.

A series of crosses were effected between differing forms, which it is hoped will result in securing types different from those now in cultivation. The flowers of several plants of *L. longiflorum* were fecundated with pollen taken from flowers of *L. harrisii*, and vice versa. The seedlings from these crosses have already flowered, and the results are very satisfactory. They are especially valuable in pointing out future work along the same lines. The progress made by the seedlings as a result of these crosses is somewhat remarkable, in that they bore flowers in a comparatively short time after germinating. Plate III shows the capsules and seeds of *L. harrisii* crossed with *L. longiflorum*. Plate VII represents the different stages of germination. In Plate IV, fig. 1, the seedlings are in 2-inch pots, about five weeks after making their appearance above the soil. In three of the seedlings the seed coats are seen adhering to the ends of the seed leaves. A later stage is indicated in Plate IV, fig. 2, where the seedlings are more advanced, having made from two to four character leaves. This represents the progress made in ten weeks after germinating. From this stage onward the growth is quite rapid.

In Plate V, fig. 1, is seen a seedling with all the radical leaves showing, but not fully developed. This is the stage just previous to the development of the flower stem. The bulb at this period is nearly 3 inches in circumference and is wholly formed of the bases of the leaves. This particular bulb was in no way injured by the soil being washed from the roots; it was repotted and formed a stem, which bore two flowers.

Of the two seedlings in flower (Pl. I) the one to the left, marked "A," is *L. longiflorum*, crossed with *L. harrisii;* that to the right, marked "B," is the reciprocal cross. There is a very marked difference in the size of the flowers, the one to the right being fully 2 inches longer than the other. This difference was observable in nearly all of the individuals of the *L. harrisii* × *L. longiflorum* batch.

The bulbs shown in Plate V, fig. 2, are the largest which were formed. They belong to the *L. harrisii* × *L. longiflorum* batch and were harvested on the 15th of August, ten months and fourteen days after the seeds germinated. The bulb to the right measured 6 inches in circumference. Each of the plants bore three average-sized flowers. It will be seen that the bulb formed as in Plate V, fig. 1, has disappeared, and new bulbs with true scales have formed at the bases of the stems.

PLANTING IN THE OPEN GROUND.

Batches of lilies for experimental work in ascertaining localities favorable to the production of bulbs should be planted late or early according to the particular section of the country in which the experiment is to be conducted. In the North it may be considered safe to put them in the ground during the latter half of September. Farther south the planting should be delayed so that there may be no danger of the growth showing above ground previous to freezing weather.

In the North as hard freezing weather approaches the ground in which the bulbs are planted should have a heavy mulch of such a nature as to be easily removed in spring. This mulch will serve several purposes; it will help to keep the soil around the bulb at an equable temperature and prevent rapid thawing and freezing at and near the surface of the soil. Throughout the South, especially in the districts within the frost belt, the mulch need not be heavy, and should consist of half-decayed leaves or very old manure, so that there will exist no necessity for its removal when the growths are making their way through the soil. It should not be applied too soon, as there is then a danger of the soil being kept too warm, thus encouraging the shoots to push above the soil before the advent of cold weather. In all cases a mulch should be spread over the soil during hot, dry weather.

So far as the requirements of the lilies are understood, correct conditions would not be supplied by repeated cultivation between the rows. Those conditions could be secured best by a system of mulching to keep the sun from warming the soil too much near the surface or else by the substitution of some kind of a shade crop to protect the soil from the sun's rays. This crop would, of course, have to be of such a nature as not to rob the soil of too much of the food and moisture necessary for the growth of the lilies.

Again, the bulbs may be grown in beds, as in the Bermudas, and close enough together to shade the ground to a certain extent. In any event, the cool and fairly moist condition of the surface soil is a most essential point to be observed in the cultivation of the lily. In planting, the depth to which the bulbs should be placed should range from 4 to 6 inches, according to the size of 1-year-old bulbs.

In this, as in every other crop, there are so many details essential to successful cultivation, all differing with the localities, that the above directions must be construed merely as suggestions. Lily farming in the United States is so new that one must not be discouraged if at first failure results from treatment which applied to most other crops would mean success.

REPRODUCTION FROM SEED.

A point greatly in favor of raising *L. longiflorum*, *L. harrisii*, or any of the other forms from seed, to constitute the crop of marketable bulbs, is that from one to two years' time is saved in the operation over the scale method. This in itself will appeal to most people; but it is by no means the best feature of the method, as will be shown later on.

Plate V, fig. 2, shows bulbs which measured 6 inches in circumference at a period only ten months after the seeds germinated. These bulbs each produced three flowers above the average size. Much poorer plants are sometimes retailed at $1 each. So easy is it to raise flowering plants from seed that the writer is inclined to believe that should the time come when the disease is more rampant than at present, growers will, when the subject is better understood, be able to raise their own bulbs by a system of greenhouse treatment and have the plants from seed flowering in pots ready to be sold within a year.

This would probably seem like a fairy tale to the participants of the lily conference held in London in 1901. One of the papers read at that time states that many species of *Lilium* must have from ten to twelve years to develop a flowering bulb from the seed. Elwes, in his Monograph of the Genus Lilium, says of *L. longiflorum:* "In three or four years at most flowering bulbs will be produced from seed if the young plants are properly treated." This means that by the English method of raising seedlings the plants in flower take five years at most to reach that stage.

There exists a widespread belief that in raising plants from seed a long time elapses before they come into bloom, and it is urged against the seed method that a certain percentage of the plants in a batch are late in coming into flower. It should be remembered, however, that this is more or less the case with all kinds of plants where the method of vegetative reproduction is suddenly changed to that of reproduction from seed. In all cases this irregularity of the blooming period lasts only for a time.

There is a possibility of fixing types in seedling lilies as in all other plants raised from seed, but just how long a time would elapse before this desired result would be attained has not been determined. A few generations would probably cover the period.

But even were there no possibilities of fixing types from seminal reproduction, the supposition that this method of propagation is a drawback because of late bloomers is very erroneous. This point has been raised against the method chiefly because it has never been tried systematically. A batch has been raised giving only about 75 per cent of bulbs that can be depended upon to produce plants that will open their flowers within, say, a period of ten days; but even so, with the gain of increased vigor and the saving of time required in the production of a marketable bulb, it will pay handsomely, even if the late bloomers are discarded while in the growing stage in the field and only the early blooming bulbs are harvested. However, there is no necessity for so radical a treatment. The early bloomers can be separated from those which bloom late, and sold accordingly. There is a demand for healthy bulbs at whatever time they bloom. Furthermore, by judicious selection of seed parents—that is, those which come earliest into bloom, having other desirable characteristics to recommend them—and by careful cross-fertilization of these forms there is an absolute certainty of fixing types which will be satisfactory in every respect.

Nearly every lily has been propagated asexually up to the present time, and the system is, to a certain extent, answerable for the wretched condition of the crops, which, even with intelligent care in our greenhouses, show from 40 to 60 per cent of diseased plants. Most growers would greatly prefer to have only 25 per cent of late bloomers in a batch of healthy bulbs from seed than that the present conditions affecting the Bermuda and Japan bulbs should continue.

EMASCULATING AND POLLINATING THE FLOWERS.

To raise seedlings of any desirable variety of *Lilium longiflorum* which will reproduce as nearly as possible the same characters possessed by the parents, it is necessary to take precautions against the possibility of pollen from less desirable forms being deposited upon the stigmas of the flowers selected to bear seed. In the flower of the Easter lily the anthers reach maturity a little in advance of the period when the stigma is in a receptive condition. The early ripening of the pollen and the large size of the anthers make it easy to remove the stamens at quite an early stage in the life of the flower.

Emasculation can be performed with a certain degree of safety after the perianth segments expand, but it is accomplished with greater certainty while the flower is in the bud stage. When the operation is performed early it seems to divert to the pistil the substance which otherwise would be utilized in the development of the stamens. Thus, if the stamens are allowed to remain and pollinate the same flower with its own pollen, or that from the flower of another individual, the resulting capsule of seed is smaller than that borne by an artificially pollinated flower which had previously been emasculated. To remove the stamens at an early stage it is necessary to cut off one or two divisions of the perianth for at least one-third of their length. The stamens, being very large, are then easily removed with the aid of a pair of forceps. The condition of the stigma most favorable for the reception of the pollen is indicated by its having acquired full size and by its color changing from a greenish white to creamy white. This period occurs just before the surface of the stigma is copiously covered with a viscid secretion. Before the secretion appears the pollen takes immediate effect. Fecundation, when successful, is indicated by the rapid withering of the perianth; also by the ovary, which, in a few days, will assume a vertical position instead of remaining horizontal. (Pl. II, figs. 1 and 2.) In this position it will continue, in the absence of fertilization, until it falls off or withers.

It is of importance that the actual work of applying pollen from the anthers of one flower to the stigma of another be performed during the early part of the day, choosing a time when the sun is likely to be unobscured for several hours. The air should also be dry and warm. It is not necessary to use a brush in transferring the pollen. With a pair of forceps an anther may be removed by severing a filament at about half an inch below the point of attachment. The pollen grains on a single anther are sufficient to cover thoroughly the surface of the stigma. While held by the forceps the anther should be rubbed against the stigma until the latter is covered with the pollen grains. This condition is easily observed by the bright yellow color and copious supply of pollen. The pollinated flower should not be covered with paper bags. These, as a rule, serve well with other kinds of flowers where artificial pollination is resorted to in keeping out insects and preventing pollen being brought by other agencies, but in the flowers of Lilium they are usually hurtful, because the atmosphere surrounding the stigma is to a certain extent stagnant on account of the thick texture of the paper interfering with the free admission of air. If this condition is present while the very copious secretion is over the large stigma, some of the pollen grains decay, and the result is that a moldy growth will occur over the entire pollinated surface. Light gauze or cheese-cloth bags will be found excellent substitutes for paper bags. There is little probability of pollen grains being carried about by a movement of the atmosphere or the visitations of insects, but it is better to guard against the danger of undesirable pollen gaining access to the stigma.

In all of the varieties the seed vessels take from eight to ten weeks to reach maturity. This is indicated by a change of color from pea-green to a light straw-colored hue, at first near the apex, then gradually extending toward the base. When the basal part changes its color the seeds are ripe. The seed vessel at this stage begins to dehisce, starting at the apex and splitting into three parts, each part containing two rows of seed closely arranged lengthwise. When the vessels begin to open they should be gathered and kept in an uncovered receptacle until most of the moisture in the walls of the seed vessel has evaporated. In a day or two the seeds must be removed from the capsules. They are then damp to the touch and should not be excluded from the air while in this state, as there is danger of their becoming moldy. They should be spread out on trays for a day or so to dry. Afterwards they can be kept in jars until wanted for sowing.

SOWING THE SEEDS.

In places having a similar winter climate to that of the Bermudas, or where the minimum temperature does not fall below 45° F., the seedlings may be raised out of doors without the aid of greenhouse structures but with the protection of sash throughout the germinating period and until the plants have made the first three or four leaves.

The plants can be brought to this stage by the beginning of September and transferred to convenient distances apart in beds, where they will make rapid growth. The seeds should be sown in beds in rows from 5 to 6 feet wide. To have the soil in which the seed is to be sown of sufficient warmth to promote a steady growth, there should be at least 3 inches of stable litter and leaves placed in the bottom of the bed. Loamy soil, mixed with one-third vegetable humus, should be placed over the litter to a depth of at least 6 inches. This should be well firmed and raked smooth. The seed should be sown quite thickly, as the seedlings have small, narrow leaves and occupy but little space until they are ready for pricking off. After the surface of the seed bed has been raked quite smooth the seeds should be sown evenly over the bed, from 6 to 10 to each square inch of surface, according to the quality of the seed. The seeds can be pressed into the soil with the back part of a spade or a smooth piece of board and covered with one-half inch of sifted and sterilized soil composed of loam and leaf soil in equal parts. The soil, if sterilized, will prevent the disturbance of the surface in removing weeds. The surface should be pressed moderately firm and watered with a fine sprinkler only when the soil appears to be on the dry side. The surface of the bed can be kept in excellent condition for successful germination by covering it with an inch of sphagnum moss, which should be sprinkled occasionally, and the soil should be examined frequently to ascertain its condition.

The seeds require a considerable time in the ground before the first leaf appears above the surface. Therefore, to provide seedling plants for a large crop the seed beds will occupy a comparatively small space. They will thus be easily tended, so far as watering, shading, and weeding are concerned, until the seedlings have attained sufficient size to warrant pricking off. If bulbs are planted and seeds sown at the same time, the bulbs naturally can be flowered quicker than the seedlings, but only by a few weeks. Therefore, the seeds should be sown early—say, during the month of June. When sown at this period the seedlings will attain a fair size during warm weather, and will all the better be able to withstand the lower temperature of the winter months.

With regard to raising seedlings in the Middle and Northern States, there is little probability of success unless the seed is sown, say, during the month of January indoors and the seedlings are transplanted to outdoor beds as soon as the weather permits. For experiments of this nature the seeds would necessarily have to be of the previous season's crop, and in order to have them ripen late, so that as short a time as possible would elapse between ripening and sowing, the seed-bearing plants should be grown outdoors.

PRICKING OFF THE SEEDLINGS.

The seedlings will bear pricking off as soon as the seed leaves reach full size. Nothing is gained, however, by undertaking the operation at this early stage. It is more easily accomplished after the plantlets have made two or three leaves. They should be transferred to beds similar in size to those in which the seeds were sown and at a distance of from 2 to 3 inches apart. The work of pricking off can be very rapidly done, and wholly with the fingers or without the aid of a dibble. The protection of shaded sash may be given for the first few days if found necessary. When the plants are supplied with leaves of such size as to be in danger of crowding each other they should be removed to the field beds. It may be stated that the plants, even in their younger stages, are not at all impatient of removal. Plate V, fig. 1, shows a plant which was grown in a 5-inch pot, the soil being removed from the roots to show the size of bulb at a certain date from germinating. This bulb was repotted and came into flower seemingly none the worse for its experience.

PLATES.

DESCRIPTION OF PLATES.

PLATE I. Frontispiece.—Seedling lilies in bloom. A.—*Lilium longiflorum* × *L. harrisii*. B.—*Lilium harrisii* × *L. longiflorum*, showing large flower. Photographed April 16, 1902, six months and thirteen days after germinating.

II. Fig. 1.—*Lilium longiflorum*, tall-growing variety from Japan, showing the vertical position assumed by the ovaries after fertilization. Fig. 2.—*Lilium longiflorum*, low-growing variety from Japan, with long, broad leaves. The capsules show the progress made at a period of three weeks after pollination. Fig. 3.—*Lilium longiflorum*, tall-growing variety from Japan, with long and broad leaves along the entire length of the stem.

III. Capsules and seeds of *Lilium harrisii* × *L. longiflorum*. Flowers pollinated April 3; seeds ripe June 14, 1901.

IV. Fig. 1.—*Lilium harrisii* × *L. longiflorum* seedlings in 2-inch pots. Seeds sown June 26, 1901, germinated October 3, potted October 28, photographed November 9, 1901. Fig. 2.—*Lilium harrisii* × *L. longiflorum* seedlings in $2\frac{1}{2}$-inch pots ten weeks after germination.

V. Fig. 1.—*Lilium harrisii* × *L. longiflorum*, showing size of bulb February 16, 1902, eighteen weeks after germination. Fig. 2.—Seedling bulbs of *L. harrisii* × *L. longiflorum*. The bulb to the right measured 6 inches in circumference. These bulbs were grown from the seed within ten months.

VI. Diseased Bermuda lily bulbs. A.—Cross section through a diseased bulb that began to grow and then died. The tissue was eaten out by the bulb mites. B.—Cross section through a bulb that failed to grow. The bud was eaten out by mites.

VII. Germination of *Lilium longiflorum*. 1. Sprouting of the seed. 2. An older stage, where the cotyledon shows the bending, while the apex remains closed in the seed absorbing the endosperm. 3. Still older. 4. The cotyledon has now unfolded itself, raising the attached seed high above the level of the ground. 5. The first leaf l' is developed while the cotyledon is as above. 6. The seed has dropped and three leaves are now developed; also two secondary roots. The roots show wrinklings above, indicating their contractile power in drawing the bulblet deeper and deeper into the soil.

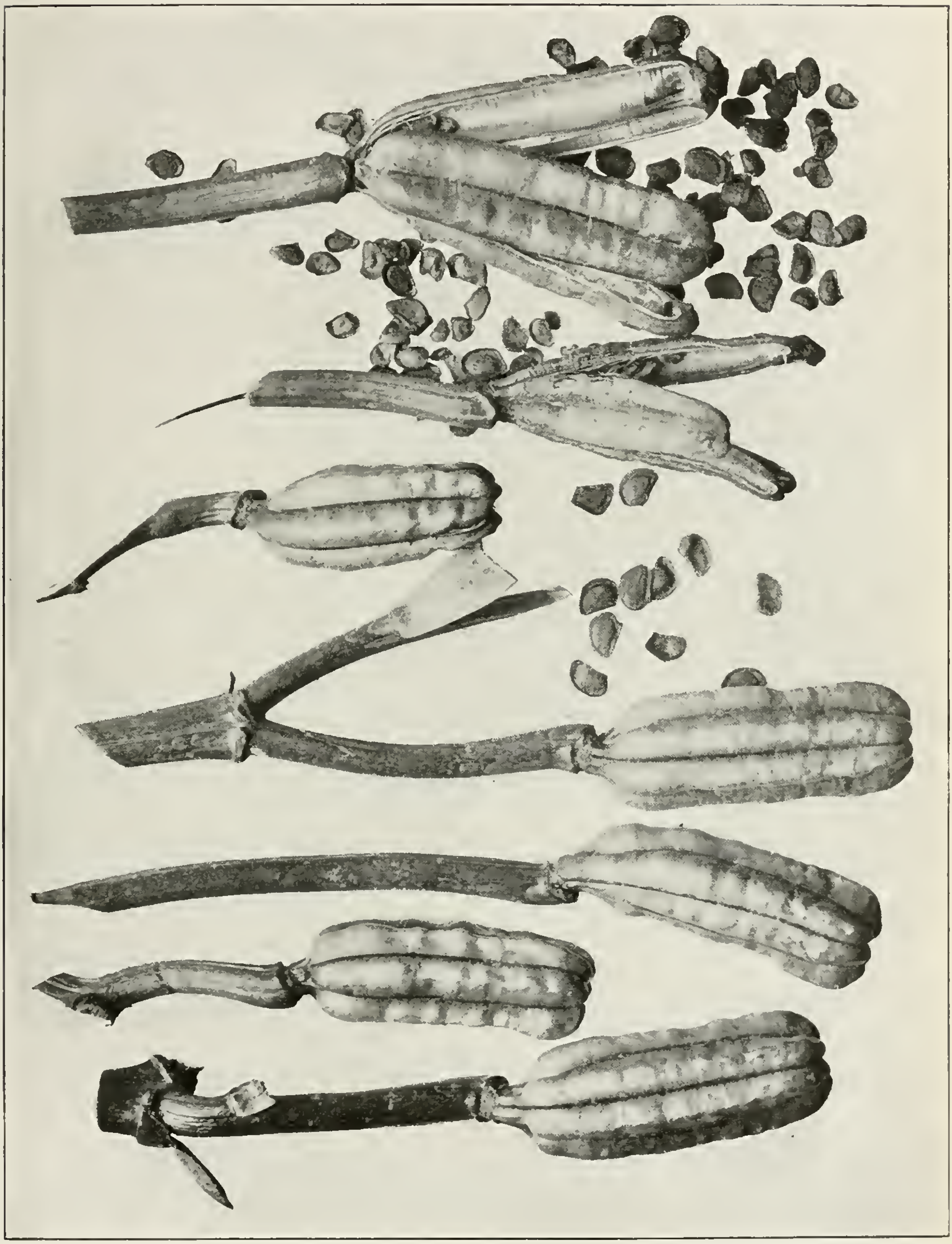
Fig. 1.

Fig. 2.

Fig. 3.

LILIUM LONGIFLORUM.

Figs. 1 and 3. Tall-growing variety from Japan; Fig. 2. Low-growing variety from Japan.



CAPSULES AND SEEDS OF LILIUM HARRISII × L. LONGIFLORUM.

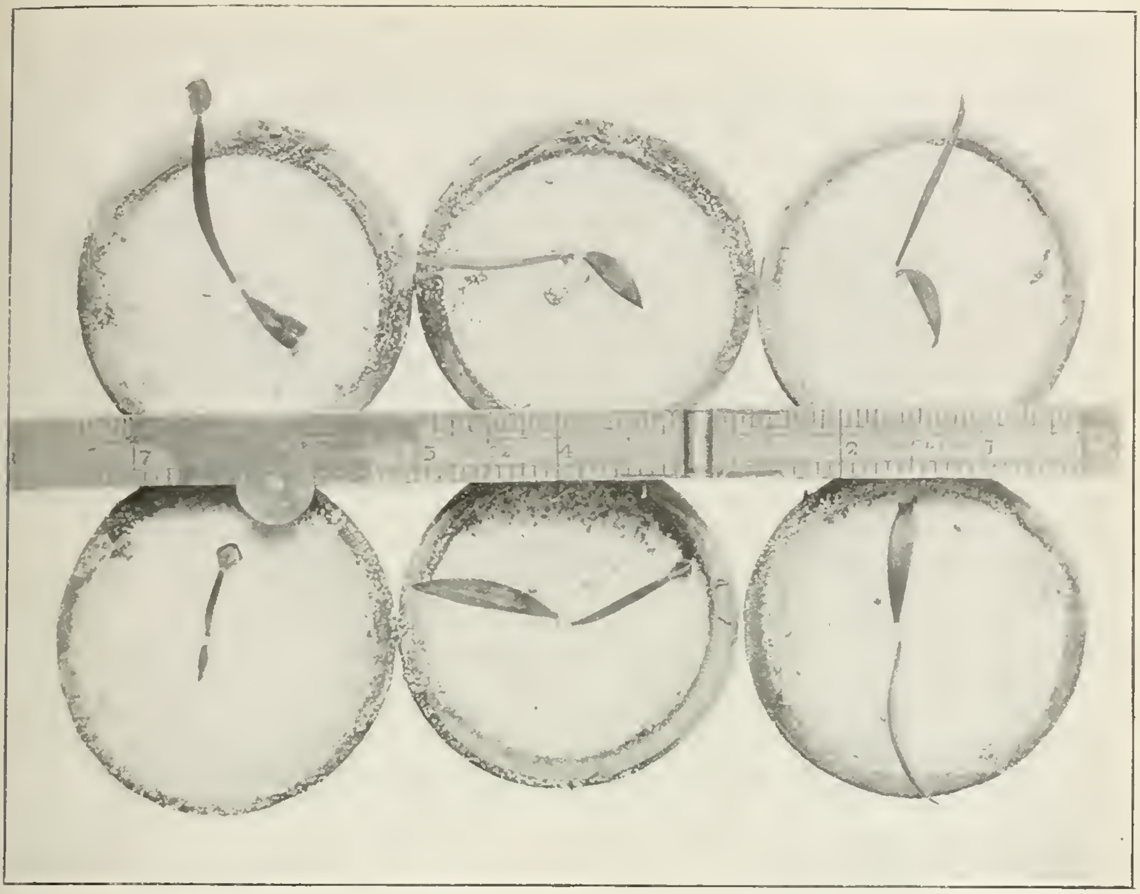


FIG. 1.—LILIUM HARRISII × L. LONGIFLORUM SEEDLINGS IN 2-INCH POTS, FIVE WEEKS AFTER GERMINATION.

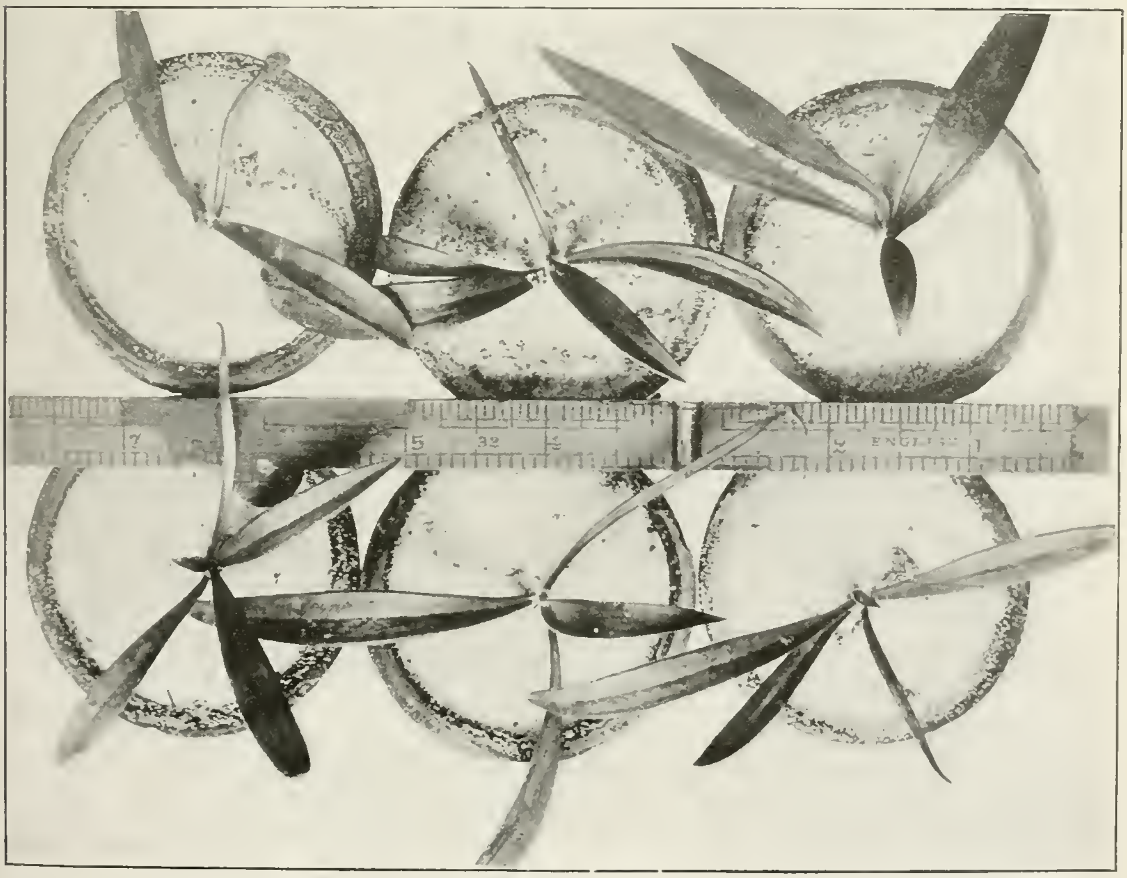


FIG. 2.—LILIUM HARRISII × L. LONGIFLORUM SEEDLINGS IN 2½-INCH POTS, TEN WEEKS AFTER GERMINATION.

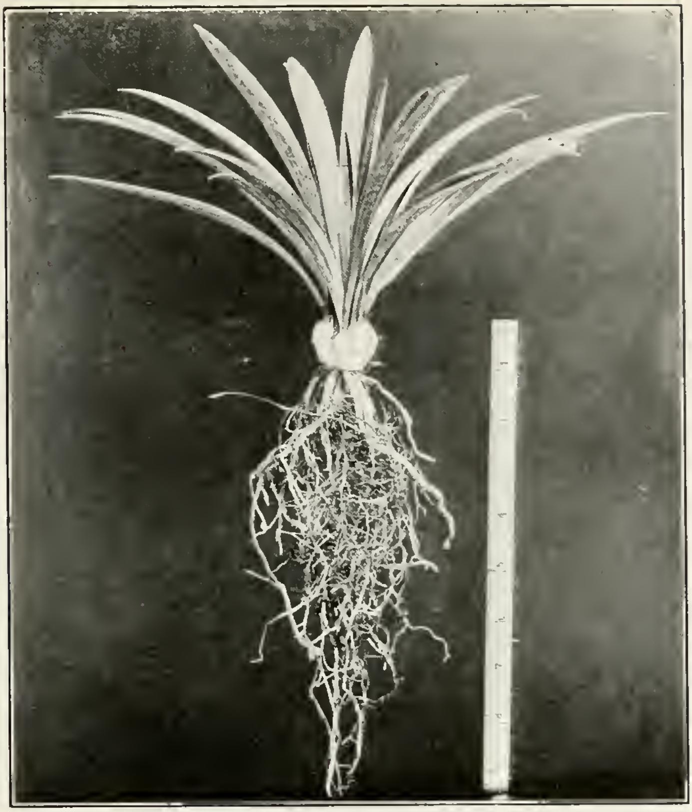
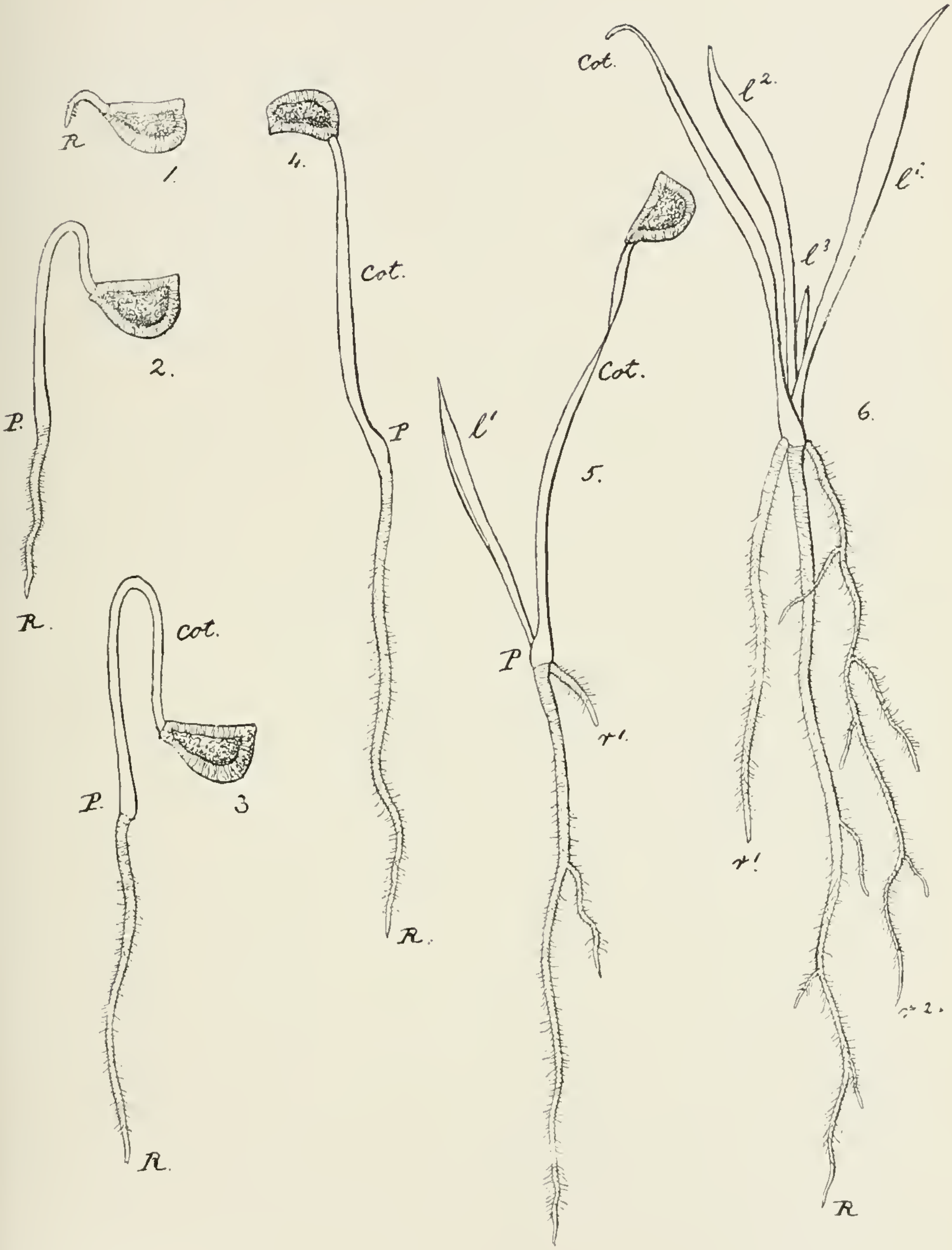


FIG. 1.—LILIUM HARRISII × L. LONGIFLORUM, SHOWING BULB EIGHTEEN WEEKS AFTER GERMINATION.

FIG. 2.—SEEDLING BULBS OF LILIUM HARRISII × L. LONGIFLORUM, GROWN FROM SEED WITHIN TEN MONTHS.

DISEASED BERMUDA LILY BULBS.

A, Cross section of bulb that began to grow though the tissue was eaten by mites: *B*, Cross section of bulb, with bud eaten by mites, that failed to grow.



GERMINATION OF LILIUM LONGIFLORUM.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 40.

B. T. GALLOWAY, *Chief of Bureau.*

COLD STORAGE, WITH SPECIAL REFERENCE TO THE PEAR AND PEACH.

BY

G. HAROLD POWELL,

ASSISTANT POMOLOGIST IN CHARGE OF FIELD INVESTIGATIONS,

AND

S. H. FULTON,

ASSISTANT IN POMOLOGY.

POMOLOGICAL INVESTIGATIONS.

ISSUED SEPTEMBER 18, 1903.

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1903.

BULLETINS OF THE BUREAU OF PLANT INDUSTRY.

The Bureau of Plant Industry, which was organized July 1, 1901, includes Vegetable, Pathological, and Physiological Investigations, Botanical Investigations and Experiments, Grass and Forage Plant Investigations, Pomological Investigations, and Experimental Gardens and Grounds, all of which were formerly separate Divisions, and also Seed and Plant Introduction and Distribution, the Arlington Experimental Farm, Tea Culture Investigations, and Domestic Sugar Investigations.

Beginning with the date of organization of the Bureau, the several series of bulletins of the various Divisions were discontinued, and all are now published as one series of the Bureau. A list of the bulletins issued in the present series follows.

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9. The North American Species of Spartina. 1902. Price, 10 cents.
10. Records of Seed Distribution and Cooperative Experiments with Grasses and Forage Plants. 1902. Price, 10 cents.
11. Johnson Grass: Report of Investigations Made During the Season of 1901. 1902. Price, 10 cents.
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21. List of American Varieties of Vegetables for the Years 1901 and 1902. 1903. Price, 35 cents.

[Continued on p. 3 of cover.]

ELBERTA PEACHES, STORED FOR TWO WEEKS IN A TEMPERATURE OF 36° F. (UPPER FIGURE) AND 32° F. (LOWER FIGURE.) NATURAL SIZE.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 40.

B. T. GALLOWAY, *Chief of Bureau.*

COLD STORAGE, WITH SPECIAL REFERENCE TO THE PEAR AND PEACH.

BY

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AND

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POMOLOGICAL INVESTIGATIONS.

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BUREAU OF PLANT INDUSTRY.

B. T. GALLOWAY, *Chief of Bureau.*

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LETTER OF TRANSMITTAL

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., May 11, 1903.

Sir: I have the honor to transmit herewith a paper entitled "Cold Storage, with Special Reference to the Pear and Peach," and respectfully recommend that it be published as Bulletin No. 40 of the series of this Bureau.

This paper was prepared by Mr. G. Harold Powell, Assistant Pomologist in Charge of Field Investigations, and Mr. S. H. Fulton, Assistant in Pomology, and has been submitted by the Pomologist with a view to publication.

The illustrations which accompany this report, comprising five colored and two half-tone plates, are considered essential to a full understanding of the text.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

The protection of fresh fruits, through the agency of low temperatures in cold storage houses, against their normal deterioration and decay has become in recent years one of the most important factors affecting the prosperity of the commercial orchardists of the United States. Practical experience has demonstrated the necessity for more complete and accurate knowledge regarding the possibilities of preserving fruit in wholesome condition in this way and the underlying principles that govern the behavior of fruits thus stored, as well as the effect of different cultural and climatic conditions upon the behavior of stored fruit.

The investigation of different phases of this subject was begun in the summer of 1901 and is still in progress. While the completion of these important investigations, which involve repeated experiments with different varieties of fruit grown under the varying climatic conditions of different parts of the country and stored in different warehouses, will of necessity extend over a considerable period of time, the important economic results thus far attained make the publication of this preliminary report upon the subject advisable at this time. In this report certain general principles are stated for the benefit of fruit growers, dealers, and storage men, and such specific application is made of these principles to the peach and pear in storage as experience thus far has proved desirable. Other phases of the work are in progress and will be discussed in future publications.

This bulletin has been prepared by Mr. G. Harold Powell, Assistant Pomologist in Charge of Field Investigations, and Mr. S. H. Fulton, Assistant in Pomology, as the result of investigations made by them under the direction of Mr. William A. Taylor, Pomologist in Charge of Field Investigations. The work, in so far as these fruits are concerned, has been closely associated with the experimental export shipments of fruits, which will be reported upon in a future bulletin.

G. B. Brackett,
Pomologist.

Office of Pomological Investigations,
Washington, D. C., March 19, 1903.

CONTENTS.

ILLUSTRATIONS.

COLD STORAGE, WITH SPECIAL REFERENCE TO THE PEAR AND PEACH.

THE FUNCTION OF COLD STORAGE.

Fruit is placed in cold storage to retard the life processes which as they progress cause it to ripen and decay. The ripening goes forward more slowly in low temperatures, but still continues in the lowest temperatures in which the fruit may be safely stored. Fruit is stored also to prevent the rapid spread of fungous diseases which cause its premature decay.

A fruit is a living organism, with a life history extending from its earliest growth to final decay, and the cold-storage treatment is designed to retard development without injuring its usefulness in other respects. The rapidity of ripening in the storage temperature depends principally on the habit of the fruit, the degree of maturity at which it enters the storage house, and the temperature and other conditions in which it is stored. It is influenced also by other factors during its growth and by the treatment it receives before it reaches the storage house.

The warehouse is expected to supply a uniform temperature of the desired degree of cold through the storage compartments during the storage season. It is expected to be managed in other respects so that an unusual loss in the aroma and flavor of the fruit, in texture or in color, or through decay, may not be attributed to a poorly constructed or installed plant, or to its negligent or improper management. If the temperatures are maintained reasonably uniform at the point desired by the fruit storer, if the rooms are kept pure and sweet and laden with sufficient moisture, and if the fruit is handled properly within the warehouse, the storage house fulfills its function in the preservation of fruits. If, on the other hand, the temperatures fluctuate unduly and the fruit freezes to the point of injury, or is made to ripen prematurely, or the rooms are not properly managed, or if ordinary care is not exercised in other respects in the management of the house or the handling of the fruit, the storage house fails to fulfill its proper function.

The warehouseman does not insure the fruit against natural deterioration. He holds it in storage as a trustee, and in that relation is bound to use only that degree of care in the management of the warehouse that a man of ordinary prudence would exert under the circumstances in protecting the goods if they were his private property.

It is frequently assumed that the cold-storage house in some mysterious way levels the differences that naturally exist in the fruits of a given kind, causing all the apples of a variety, for example, to keep alike. No assumption, however, could be more fallacious, and it is probable that no one aspect of the storage business has led to more misunderstandings between the men who store fruit and the warehousemen than this unfortunate impression. Cold storage can not improve the physical condition of fruit, and is in no way responsible for the deterioration that may arise from improper picking, grading, packing, and handling before the storage house is reached.

Fruits of all kinds are profoundly modified by the climate, the soil, the age and health of the trees, and the conditions to which they are subjected during their development, and these acquired differences will manifest themselves in the storage rooms just as they do in normal storage ripening, except that they usually appear later.

THE PURPOSES OF FRUIT STORAGE.

In the consideration of any storage problem it is important to pay due attention not only to the influences which affect the keeping quality of fruits and to the function of the cold-storage plant, but also to the purpose for which the fruit is stored. The fruit dealer may not always desire to retard the development of the fruit to the greatest possible extent. For the Holiday trade it may be advisable to have certain varieties of apples or pears in condition for immediate consumption during the Christmas season, though the same varieties might be retarded until April if stored in a lower temperature. The fruiterer who takes the fruit from the storage house to the fruit stand from day to day may desire it to ripen and color considerably before it leaves the storage house. The dealer, on the other hand, who stores the same varieties in large quantities for export trade or for late domestic markets has a different object in view, and the two distinct purposes would influence the storage treatment of each.

It is equally important to consider the requirements of the market in the storage of different fruits. The commercial use of a particular fruit is limited principally to the season when people are in the habit of buying it, and beyond that period the demand is restricted, unless there is a failure in the supply of other fruits that normally fill the market at that time. It is possible to hold many varieties of pears till late winter or early spring, but the usual demand for them at that time would not warrant their storage in large quantities, as apples and oranges are then at the height of their season. In fact, it is doubtful whether it is advisable to store pears of any kind in large quantities after the middle of November. For the same reason it is usually not a good plan to hold apples in large quantities later than the 1st of May, when fresh vegetables and the new crop of Southern fruits begin to fill the markets. The general principles, therefore, which govern the preservation of fruits and their relation to the markets can be understood only when these various factors are considered together.

INFLUENCE OF COLD STORAGE ON THE PEAR INDUSTRY.

Before the advent of the cold-storage business the supply of summer pears frequently exceeded the demand. This condition of the markets, which were demoralized in hot, humid seasons, pertained especially to the early varieties, like the Bartlett, which ripen in hot weather and need to be sold in a short time to prevent heavy losses from rapid decay. The introduction of the refrigerator car and of the cold-storage warehouse, together with the rapid growth of the canning industry, has done much to improve the pear situation by artificially establishing a well-regulated and more uniform supply of fruit throughout a longer period of time. The pear acreage of the country has more than doubled within a decade, and is enlarging the relative importance of cold storage to the pear-growing business, though a large part of the increase, especially in California, along the Atlantic coast from New Jersey southward, in Texas, and in the Central West, is primarily related to the canning industry.

Pear storage has developed most largely in the East. In New York and Jersey City from 60,000 to 100,000 bushels of summer pears, 30,000 to 60,000 bushels of later varieties, and many cars of California pears are stored annually. In Boston, since 1895 there have been stored each year from 5,000 to 15,000 bushels of early pears, principally Bartlett, and from 7,000 to 20,000 bushels of later varieties, such as Anjou, Bosc, Angouleme (*Duchess*), Seckel, and Sheldon. In Buffalo 10,000 bushels are sometimes stored in a single season, and in Philadelphia from 30,000 to 35,000 bushels. While there are no accurate statistics available and the quantity fluctuates from year to year, it is probable that as many as 300,000 bushels are stored in a single year throughout the country at large.

PRACTICAL DIFFICULTIES IN PEAR STORAGE.

There are many practical difficulties in pear storage. The early-ripening varieties which mature in hot weather, like the Bartlett, often "slump" before they reach the storage house, or are in soft condition, especially if they have been delayed in ordinary freight cars in transit. They may afterwards decay badly in storage, break down quickly on removal, or lose their delicate flavor and aroma. When stored in a large package like the barrel, the fruit, especially of the early varieties, often softens in the center of the package, while the outside layers remain firm and green. Frequently no two shipments from the same orchard act alike, even when stored in adjoining packages in the same room, and the warehouseman and the owner, not always knowing the history of the fruit, are at a loss to understand the difficulty. It has been the aim in the fruit-storage investigations of the Department of Agriculture to determine as far as possible the reasons for some of the pear-storage troubles, and to point out the relation of the results to a more rational storage business.

OUTLINE OF EXPERIMENTS IN PEAR STORAGE.

The investigations in pear storage are of a preliminary nature only. The experiments undertaken have been planned with a view to determining the influence in the storage room of various temperatures, of the character of the storage package, of a fruit wrapper, of the degree of maturity of the fruit when picked, and of other factors in relation to the ripening processes in the storage house, and also to ascertain the behavior of the fruit and its value to the consumer when placed on the market.

The Bartlett and the Kieffer pears principally were used in the experiments, but several other kinds have been under limited observation. The Bartlett represents the delicate-fleshed, tender pears, ripening in hot weather, which are withdrawn from storage before the weather becomes cool. The Kieffer, on the other hand, is a coarse, hard pear, ripening later in the fall in cooler weather, and in which the normal ripening processes are slower. It is a longer keeper, and like other fall varieties is withdrawn in cool weather.

The Bartlett experiments extended through the season of 1902. The fruit was grown by Mr. F. L. Bradley, Barker, N. Y., in a twelve-year-old orchard on a sandy loam, with a clay subsoil. The orchard is a half mile from Lake Ontario and is 50 feet above the level of the lake. The fruit, which was full grown, but green, was picked early in September, and was packed in tight and ventilated barrels, in 40-pound closed boxes, and in slat bushel crates. Part of the fruit in each lot was wrapped in unprinted news paper, and an equal amount was left unwrapped. Part was forwarded at once by trolley line to the warehouse of the Buffalo Cold Storage Company at Buffalo, N. Y., and a similar quantity was held four days before being stored. The fruit reached the storage house within ten hours after leaving the orchard.

The Kieffer experiments have extended over two years. In 1901 the fruit was grown by Mr. M. B. Waite, Woodwardsville, Md., in a Norfolk sandy soil, on rapidly growing five-year-old trees, from which the fruit was large, coarse, and of poor quality. It was stored in the cold-storage department of the Center Market at Washington, D. C. In

1902 the fruit with which the experiments were made was grown by Mr. S. H. Derby, Woodside, Del., on heavy-bearing ten-year-old trees on sandy soil with a clay subsoil. The fruit was smaller, of finer texture, and of somewhat better quality than that used the previous year. It was stored in the cold-storage department of the Reading Terminal Market in Philadelphia, Pa.

The Kieffers were picked at three degrees of maturity: First, when two-thirds grown, or before the fruit is usually picked; second, ten days later, or about the time that Kieffers are commonly picked, and third, ten days later, when the fruit was fully grown and still green, but showing a yellowish tinge around the calyx. In each picking, part of the fruit was shipped to storage and was placed in rooms with a temperature of 36° and 32° F. within forty-eight hours. Equal quantities stored in each temperature were wrapped in parchment paper, in unprinted news paper, and were left unwrapped. A duplicate lot of fruit remained in a common storage house ten days in open boxes, when it was packed in a similar manner and sent to storage. This fruit colored considerably during the interval, but was still hard and apparently in good physical condition on entering the storage house. The pears were stored in 40-pound closed boxes and in five-eighths bushel peach baskets. One hundred and fifty bushels were used in the experiments.

THE INFLUENCE OF THE DEGREE OF MATURITY ON KEEPING QUALITY.

The experiments with the Kieffer pear show that under conditions similar to those in Delaware and eastern Maryland this variety may safely be picked from the same orchard during a period of at least three weeks, or when from two-thirds grown to full size, and that the fruit in all cases may be stored successfully until the Holidays, or much longer if there is still a demand for it. It is absolutely essential that the fruit be handled with the greatest care, that it be sent at once to storage after picking, that it be packed carefully to prevent bruising (preferably in small packages, like a bushel box), and that it be stored in a temperature not above 32° F. if it is desired to hold it for any length of time. If stored by the middle of October, the fruit, by the latter part of December, will take on a rich, yellow color when kept in a temperature of 32° F., and earlier if a higher temperature is used. The fruit may be withdrawn during the Holidays, and will stand up, i. e., continue in good condition, for ten days or longer if the weather is cool, and will retain its normal quality if the rooms have been properly managed. While the later picked fully grown pears keep well, they are already inferior in quality at the picking time, as the flesh around the center is filled with woody cells, making it of less value either for eating in a fresh state or for culinary purposes. These coarse cells in the Kieffer and some other late varieties do not develop in the early-picked fruit to so large an extent. Pears of all kinds need to be picked before they reach maturity and to be ripened in a cool temperature if the best texture and flavor are to be developed. It is a matter of practical judgment to determine the proper picking season, but for cold storage or other purposes the stem should at least cleave easily from the tree before the fruit is ready to pick. Many trees bear fruit differing widely in the degree of maturity at the same time, and in such cases uniformity in the crop can be attained only when the orchard is picked several times, the properly mature specimens being selected in each successive picking. This practice not only secures more uniformity in ripeness, but the fruit is more even and the average size is larger than when all the pears are picked at the same time.

THE INFLUENCE OF DELAYED STORAGE ON KEEPING QUALITY.

Pears ripen much more rapidly after they are picked than they do in a similar temperature while hanging on the tree. The rapidity of ripening varies with the character of the variety, the maturity of the fruit when picked, the temperature in which it is placed, and the conditions under which it has been grown. If the fruit is left in the orchard in warm weather in piles or in packages, if it is delayed in hot cars or on a railroad siding in transit, or if it is put in packages which retain the heat for a long time, it continues to ripen and is considerably nearer the end of its life history when it reaches the storage house than would otherwise be the case. The influence of delay in reaching the storage house will therefore vary with the season, with the variety, and with the conditions surrounding the fruit at this time. A delay of a few days with the quick-ripening Bartlett in sultry August weather might cause the fruit to soften or even decay before it reached the storage house, though a similar delay in clear, cooler weather would be less hurtful. A delay of a like period in storing the slower-ripening Kieffer would be less injurious in cool October weather, though the Kieffer pear, especially from young trees, can sometimes be ruined commercially by not storing it at once after picking.

From the experiments with the Bartlett and the Kieffer pears, from which these general introductory remarks are deduced, it was found that the Bartlett, if properly packed, kept in prime condition in cold storage for six weeks, provided it was stored within forty-eight hours after picking in a temperature of 32° F.; but that if the fruit did not reach the storage room until four days after it was picked there was a loss of 20 to 30 per cent from softening and decay under exactly similar storage conditions.

The Kieffers stored within forty-eight hours in a temperature of 32° F. have kept in perfect condition until late winter, although there is little commercial demand for them after the Holidays. The fruit grown by Mr. Waite on young trees in 1901, which was still hard and greenish-yellow when stored ten days after picking, began to discolor and soften at the core in a few days after entering the storage room, though the outside of the pears appeared perfectly normal. After forty to fifty days the flesh was nearly all discolored and softened, and the skin had turned brown. The fruit from the older trees on the Derby farm in 1902, which was smaller and finer in texture, appeared to ripen as much as the Waite pears during the ten days' delay. This fruit, however, did not discolor at the core and decay from the inside outward, but continued to ripen and soften in the storage house and was injured at least 50 per cent in its commercial value by the delay. Plate II shows the condition of the Kieffer pears stored in a temperature of 32° F. as soon as picked and withdrawn in March. Plate III shows the condition of fruit picked at the same time and stored in the same temperature ten days after picking, when withdrawn in January. (See also Pl. IV, fig. 1.)

The results of the experiments point out clearly the injury that may occur by delaying the storage of the fruit after it is picked, and emphasize the importance of a quick transfer from the orchard to the storage house. If cars are not available for transportation and the fruit can not be kept in a cool place, it is safer on the trees so far as its ultimate keeping is concerned. It is advisable to forward to storage the delicate quick-ripening varieties, like the Bartlett, in refrigerator cars. The common closed freight car in warm weather soon becomes a sweat box and ripens the fruit with unusual rapidity. The results show clearly that the storage house may be responsible in no way for the entire deterioration or even for a large part of the deterioration that may take place while the fruit is in storage, and that the different behavior of two lots from the same orchard may often be due to the conditions that exist during the period that elapsed between the time of picking and of storage.

THE INFLUENCE OF DIFFERENT TEMPERATURES ON KEEPING QUALITY.

There is no uniformity in practice in the temperatures in which pears are stored. Formerly a temperature of 36° to 40° F. was considered most desirable, as a lower temperature was supposed to discolor the flesh and to injure the quality of the fruit. The pears were also believed to deteriorate much more rapidly when removed to a warmer air. In recent years a number of storage houses have carried the fruit at the standard apple temperatures, i. e., from 30° to 32° F. Large quantities of Bartlett, Angouleme, and Kieffer pears have been stored in 32° and 36° F. in the experiments of the Department. The fruit of all varieties has kept longer in the lower temperature and the flesh has retained its commercial qualities longer after removal from the storage house. Bartlett pears were in prime commercial condition four to five weeks longer, Angouleme two months longer, and Kieffer three months longer in a temperature of 32° F. Plates II and V show the condition of Kieffer pears in March, 1902, in 32° and 36° F., the two lots having received similar treatment in all respects except in storage temperatures. (See also Pl. IV, fig. 2.)

In the higher temperature the fruit ripens more rapidly, which may be an advantage when it is desirable to color the fruit before it leaves storage; but the fruit in that condition is nearer the end of its life history and breaks down more quickly on removal to a warm atmosphere.

There is a much wider variation in the behavior of pears that have been delayed in storage or that are overripe when they enter the storage room at 32° and 36° F. than in pears stored at once in these temperatures. In the higher temperature the fruit that has been improperly handled ripens and deteriorates more quickly. The lower temperature not only keeps the fruit longer when it is stored at once, but it is even more essential in preventing rapid deterioration in fruit that has been improperly handled.

THE INFLUENCE OF THE TYPE OF PACKAGE ON KEEPING QUALITY.

Pears are commercially stored in closed barrels, in ventilated barrels, in tight boxes holding a bushel or less, and in various kinds of ventilated crates. The character of the package exerts an important influence on the ripening of the fruit and on its behavior in other respects, both before it enters the storage house and after it is stored, though this fact is not generally recognized by fruit handlers or by warehousemen. The influence of the package on the ripening processes appears to be related primarily to the ease with which the heat is radiated from its contents. The greater the bulk of fruit within a package and the more the air of the storage room is excluded from it the longer the heat is retained. Quick-ripening fruits, like the Bartlett pear, that enter the storage room in a hot condition in large, closed packages, may continue to ripen considerably before the fruit cools down, and the ripening will be most pronounced in the center of the package, where the heat is retained longest. The influence of the package, therefore, will be most marked in the hottest weather and on fruits that ripen most quickly.

In the experiments of the Department of Agriculture the Bartlett pears were stored in tight and in ventilated barrels, in closed 40-pound boxes, and in slat bushel crates. After three weeks in the storage house the fruit that was stored in barrels soon after picking in a temperature of 32° F. was yellow in the center of the package, while the outside layers were firm and green. Plate VI shows the average condition of the fruit in these two positions one week after storing. After five weeks in storage the fruit in the center of the barrel was soft and of no commercial value, while the outside layers were still in good condition. The difference was still greater in a temperature of 36° F., and was more marked in both temperatures in fruit that was delayed in reaching the storage house.

In both the closed 40-pound boxes and the slat crates the fruit was even greener in average condition than the outside layers in the barrels, and it was uniformly firm throughout the entire package.

There was apparently no difference between the fruit in the commercial ventilated pear barrel and the common tight pear barrel.

With the Kieffer, which enters the storage room in a cooler condition and which ripens more slowly, a comparison has been made (in 1902) between the closed 40-pound box and the barrel, and while the difference has been less marked the fruit has kept distinctly better in the smaller package. The fruit in barrels was the property of Mr. M. B. Waite, and was under observation by the Department through his courtesy.

There is a wide difference of opinion concerning the value of ventilated in comparison with tight packages for storage purposes. No dogmatic statements can be made that will not be subject to many exceptions. The chief advantage of a ventilated package for storage appears to lie in the greater rapidity with which the fruit cools, and the quickness with which this result is attained depends on the temperature of the fruit, its bulk, the temperature of the room, and the openness of the package. The open-slat bushel crate, often used for storing Bartlett pears, with which rapid cooling is of fundamental importance, may be of much less value in storing later fruits that are cooler and which ripen more slowly, and it may be of even less importance to Bartletts in cool seasons.

The ordinary ventilated pear barrel does not appear to have sufficient ventilation to cool the large bulk of fruit quickly.

The open package has several disadvantages. If the fruit is to remain in storage for any length of time its exposure to the air will be followed by wilting, which, in fruits held until late winter or spring, may cause serious commercial injury. The ventilated package, especially if made of slats, needs to be handled with the utmost care to prevent the discoloration of the fruit due to bruising where it comes in contact with the edges of the slats.

There was little difference in the behavior of the Bartletts in the closed 40-pound boxes and the slat crates at the end of five weeks, and it would appear that a package of this size, even though closed, radiates the heat with sufficient rapidity to quickly check the ripening. Therefore the grower who uses the 40-pound or the bushel pear box for commercial purposes can store the fruit safely in this package, but if the barrel is used as the selling package, and the weather is hot, it is a better plan to store the fruit in smaller packages, from which it may be repacked in barrels at the end of the storage season. While this practice is followed in several storage houses, it is not to be encouraged, as the rehandling of the fruit is a disadvantage. Rather the use of the pear box should be encouraged as a more desirable package, both for storage and for commercial purposes.

The fruit-package question, as it relates to the storage house, may be summed up by stating that fruits like the Bartlett pear and others that ripen quickly and in hot weather may be expected to give best results when stored in small packages. If the storage season does not extend beyond early winter, an open package may be of additional value, though not necessary if the package is small. But fruits like the winter apples and late pears, which ripen in the fall in cool weather and remain in storage for a long period, should be stored in closed packages to prevent wilting. In such cases the disadvantages of a large package, like a barrel, are not likely to be serious.

THE INFLUENCE OF A WRAPPER ON KEEPING QUALITY.

The life of a fruit in cold storage is prolonged by the use of a fruit wrapper, and the advantage of the wrapper is more marked as the season progresses. In Plate VII is shown the average quantity of Kieffer pears in unprinted news paper and in parchment wrappers in comparison with the quantity of commercial unwrapped pears in boxes in January. Nearly 50 per cent of the unwrapped fruit had decayed at that time. Early in the season the influence of the wrapper is not so important, but if the fruit is to be stored until late spring the wrapper keeps the fruit firmer and brighter. It prevents the spread of fungus spores from one fruit to another and thereby reduces the amount of decay. It checks the accumulation of mold on the stem and calyx in long-term storage fruits, and in light-colored fruits it prevents bruising and the discoloration that usually follows.

Careful comparisons have been made of the efficiency of tissue, parchment, unprinted news paper, and waxed papers, and but little practical difference has been observed, except that a large amount of mold has developed on the parchment wrappers in a temperature of 36° F. A double wrapper has proved more efficient for long keeping than a single one, and a satisfactory combination consists of an absorbent, unprinted news paper next to the fruit, with a more impervious paraffin wrapper outside.

The chief advantage of the wrapper for the Bartlett pear, which is usually stored for a short time only, lies in the mechanical protection to the fruit rather than in its efficiency in prolonging its season. Its use for this purpose is advisable if the fruit is of superior grade and designed for a first-class trade. For the late varieties the wrapper presents the same advantages, and has an additional value in increasing the commercial life of the fruit. It is especially efficient, if the package is not tight, in lessening the wilting.

THE INFLUENCE OF COLD STORAGE ON THE FLAVOR AND AROMA OF THE FRUIT.

There is a general impression that cold storage injures the delicate aroma and characteristic flavors of fruits. In this publication the most general statements only can be made concerning it, as the subject is of a most complicated nature, not well understood, and involving a consideration of the biological and chemical processes within the fruit and of their relation to the changes in or to the development of the aromatic oils, ethers, acids, or other products which give the fruit its individuality of flavor.

It is not true that all cold-storage fruits are poor in quality. On the contrary, if the storage house is properly managed the most delicate aromas and flavors of many fruits are developed and retained for a long time. The quality of the late fall and winter apples ripened in the cold-storage house is equal to that of the same varieties ripened out of storage, and the late pears usually surpass in quality the same varieties ripened in common storage.

The summer fruits, like the peach, the Bartlett pear, and the early apples, lose their quality very easily, and in an improperly managed storage house may have their flavors wholly destroyed. Even in a room in which the air is kept pure the flavor of the peach seems to be lost after two weeks or more, while the fruit is still firm, much as the violet and some other flowers exhale most of their aromatic properties before the flowers begin to wilt.

It is probable that much of the loss in quality may be attributed to overmaturity, brought about by holding the fruit in storage beyond its maximum time; but it should be remembered that the same change takes place in fruits that are not ripened in cold storage, the aroma and fine flavor often disappearing before the fruit begins to deteriorate materially in texture or appearance.

On the other hand, it is certain that the quality of stored fruits may be injuriously affected by improper handling or by the faulty management of the storage rooms. Respiration goes on rapidly when the fruit is warm. If placed in an improperly ventilated storage room, in which odors are arising from other products stored in the same compartment or in the same cycle of refrigeration, the warm fruit may absorb these gases and become tainted by them, while the same fruit, if cool when it enters the storage room, will breathe much less actively, and there will be less danger of injury to the quality, even though the air is not perfectly sweet. The atmosphere of the rooms, in which citrus fruits or vegetables of various kinds—such as cabbage, onions, and celery—are stored, is often charged with the odors arising from these products, if the ventilation is not thorough. In small houses, in which a single room can not be used for each product, fruits are often stored together during the summer months, and at this period the storage air is in greater danger of vitiation, since it is more difficult to provide proper ventilation.

The summer fruits, therefore, being generally hot when placed in the storage room, are in condition to absorb the odors which are likely to affect the rooms during the warm season, and as the biological and chemical processes are normally more active in the case of such fruit than in fruits maturing later, the flavors deteriorate more quickly, even in well-ventilated rooms. The fruits that are picked in cool weather and enter the storage rooms in a cooler and less active condition are not in the same danger of contamination.

From the practical standpoint it may be pointed out that summer fruits should be stored in rooms in which the air is sweet and pure. They should not be stored with products which exhale strong aromas, and the danger of contamination is lessened if the fruit can be cooled down in a pure room before it is placed with other products in the permanent compartment provided for it. For the same reason the winter fruits should be stored in rooms in which the air is kept pure, and preferably in compartments assigned to a single fruit.

The experiments furnish no evidence that the quality deteriorates more rapidly as the temperature is lowered. On the contrary, all of the experience so far indicates that the delicate flavors of the pear, apple, and peach are retained longer in a temperature that approaches the freezing point than in any higher temperature.

THE BEHAVIOR OF THE FRUIT WHEN REMOVED FROM STORAGE.

There is a general impression that cold-storage fruit deteriorates quickly after removal from the warehouse. This opinion is based on the experience of the fruit handler and the consumer, and in many cases is well founded, but this rule is not applicable to all fruits in all seasons. The rapidity of deterioration depends principally on the nature of the fruit, on its degree of maturity when it leaves the warehouse, and on the temperature into which it is taken. A Bartlett pear, which normally ripens quickly, will ripen and break down in a few days after removal. If ripe or overmature when removed, it will decay much more quickly, and in either condition its deterioration will be hastened if the weather is unusually hot and humid. In the practical management of this variety it is fundamentally important that it be taken from storage while it is still firm and that it be kept as cool as possible after withdrawal. It is probably true that all fruits from storage that are handled in hot weather will deteriorate quickly, but it appears to be equally true that similar fruits that have not been in storage break down with nearly the same rapidity if they are equally ripe. The late pears, which ripen more slowly, if withdrawn in cool weather will remain firm for weeks when held in a cool room after withdrawal. If overripe they break down much sooner, and a hot room hastens decay in either case. The same principles hold equally true with apples. The winter varieties, if firm, may be taken to a cool room and will remain in good condition for weeks or months and retain their most delicate qualities, but in the spring, when the fruit is more mature and the weather warmer, they naturally break down more rapidly.

In commercial practice fruits of all kinds are often left in the storage house until they are overripe. The dealer holds the fruit for a rise in price, and removes it, not because the price is more satisfactory, but because a longer storage would result in serious deterioration. If considerable of the fruit is decayed when withdrawn, the evidence is conclusive that it has been stored too long. Fruit in this condition normally decays in a short time, but the root of the trouble lies not in the storage treatment, but rather in not having offered it for sale while it was still firm. In the purchase of cold-storage fruit, if the consumer will exercise good judgment in the selection of sound stock that is neither fully mature nor overripe, he will have little cause to complain of its rapid deterioration.

SUMMARY.

A cold-storage warehouse is expected to furnish a uniform temperature in all parts of the storage compartments throughout the season, and to be managed in other respects so that an unusual loss in the quality, color, or texture of the fruit may not reasonably be attributed to improper handling or neglect.

An unusual loss in storage fruit may be caused by improper maturity, by delaying the storage after picking, by storing in an improper temperature, or by the use of an unsuitable package. The keeping quality is influenced by the various conditions in which the fruit is grown.

Pears should be picked before they are mature, either for storage or for other purposes. The fruit should attain nearly full size, and the stem should cleave easily from the tree when picked.

The fruit should be stored at the earliest possible time after picking. A delay in storage may cause the fruit to ripen or to decay in the storage house. The effect of the delay is most serious in hot weather and with varieties that ripen quickly. (See Pls. II, III, and IV, fig. 1.)

The fruit should be stored in a temperature of about 32° F., unless the dealer desires to ripen the fruit slowly in storage, when a temperature of 36° or 40° F., or even higher, may be advisable. The fruit keeps longest and retains its color and flavor better in the low temperature. It also stands up longer when removed. (See Pls. II, IV, fig. 2, and V.)

The fruit should be stored in a package from which the heat will be quickly radiated. This is especially necessary in hot weather and with quick-ripening varieties like the Bartlett pear. For the late pears that are harvested and stored in cool weather it is not so important. Bartletts may ripen in the center of a barrel before the fruit is cooled down. A box holding not more than 50 pounds is a desirable storage package, and it is not necessary to have it ventilated. The chief value of a ventilated package lies in the rapidity with which the contents are cooled, but long exposure to the air of the storage room causes the fruit to wilt. (See Pl. VI.)

Ventilation is essential for large packages, especially if the fruit is hot when stored and ripens quickly.

A wrapper prolongs the life of the fruit. It protects it from bruising, lessens the wilting and decay, and keeps it bright in color. A double wrapper is more efficient than a single one, and a good combination consists of absorptive unprinted news paper next to the fruit, with a more impervious paraffin wrapper outside. (See Pl. VII.)

The quality of a pear normally deteriorates as it passes maturity, whether the fruit is in storage or not, or it is never fully developed if the fruit is ripened on the tree. The quality of the quick-ripening summer varieties deteriorates more rapidly than that of the later kinds. Much of the loss in quality in the storage of pears may be attributed to their overripeness. The quality is also injured by impure air in the storage rooms, and the warm summer pears will absorb more of the odors than the late winter varieties. The fruit will absorb less if cool when it enters the storage room. The air of the storage room should be kept sweet by proper ventilation.

The rapidity with which the fruit breaks down after removal depends on the nature of the variety, the degree of maturity when withdrawn, and the temperature into which it is taken. Summer varieties break down normally more quickly than later kinds. The more mature the fruit when withdrawn the quicker deterioration begins, and a high temperature hastens deterioration. If taken from the storage house in a firm condition to a cool temperature, the fruit will stand up as long as other pears in a similar degree of maturity that have not been in storage.

It pays to store the best grades of fruit only. Fruit that is imperfect or bruised, or that has been handled badly in any respect, does not keep well.

INFLUENCE OF COLD STORAGE ON THE PEACH INDUSTRY.

Cold storage has not materially influenced the development of the American peach business, and it is not likely to do so to any extent in the future. In the early days of peach growing the industry was localized in sections like the Chesapeake Peninsula, New Jersey, and Michigan. The use of the fruit in considerable quantities was then limited to a few near-by markets and to a short time in July, August, and September. Now peach growing is rapidly extending to all parts of the country where the climatic conditions and the facilities for transportation are favorable. The refrigerator-car service has brought the peach belts and the distant markets close together, and whenever the crop is general the New York or the Chicago trade may be supplied almost continuously from May till late October with fruit from Florida, Texas, Georgia, the Chesapeake Peninsula, New Jersey, the Ozark Mountain region, Michigan, New England, California, West Virginia, western Maryland, and other peach-growing sections.

The chief value of cold storage to the peach industry will probably lie in the temporary storage of the fruit during an overstocked market, when, however, there is a reasonable prospect of a better market within two or three weeks. It might be useful also in filling the gaps between the crops of different regions, especially when there are local failures which prevent a continuous supply. It is not now profitable to store the fruit for any length of time, nor under any circumstances unless the condition of the fruit and the storage conditions are most favorable. The life processes in the peach and the weather conditions in which it is handled make it even more critical as a storage product than the delicate Bartlett pear. In normal ripening it passes from maturity to decay in a few hours in hot, humid weather. The aroma and flavor are most delicate in character and are easily injured or lost, and the influence of any mismanagement of the fruit in the orchard, in transit, or in the storage house is quickly detected by the consumer.

PRACTICAL DIFFICULTIES IN PEACH STORAGE.

Under the most favorable conditions known at present, peach storage is a hazardous business. Before the fruit is taken from the storage house the flesh often turns brown in color, while the skin remains bright and normal. If the flesh is natural in color and texture it frequently discolors within a day or two after removal. There is a rapid deterioration in the quality of stored peaches when the fruit is held for any length of time, the delicate aroma and flavor giving way to an insipid or even bitter taste. Sometimes the flesh dries out, or under other conditions it may become "pasty." Dealers in storage peaches frequently sell them in a bright, firm condition, and shortly afterwards the purchasers complain of the dark and worthless quality of the flesh. It has often been noticed that fruit in the various packages in the same room does not keep equally well, some of it ripening and even softening while the fruit in other packages is still firm. In fact, the difficulties are so numerous that few houses attempt to store the fruit.

It has been the aim in the cold-storage investigations of the Department of Agriculture to determine, as far as possible, the cause of the peach-storage troubles and to indicate the conditions under which the business may be more successfully developed.

OUTLINE OF EXPERIMENTS IN PEACH STORAGE.

The investigations have been conducted in the cold-storage department of the Reading Terminal Market in Philadelphia, Pa., with Elberta peaches from the Hale Orchard Company, Fort Valley, Ga., and in the warehouse of the Hartford Cold Storage Company, Hartford, Conn., with Elberta and several other varieties grown by J. H. Hale at South Glastonbury, Conn.

In Georgia the fruit was packed in the Georgia peach carriers, left unwrapped, and divided into two lots, one representing fruit that was nearly full grown, well colored, and hard; the other, highly colored fruit, closely approaching but not yet mellow. Three duplicate shipments were forwarded at different times in the two bottom layers of refrigerator cars, and in each shipment part of the fruit was placed in the car within three or four hours after it was picked, and an equal quantity delayed in a packing shed from ten to fifteen hours during the day before it was loaded. Equal quantities of each series were stored in temperatures of 32°, 36°, and 40° F. The transfer from the refrigerator car to the storage house was made by wagon at night, the interval between the car and storage varying from two to five hours.

In Connecticut the fruit represented two degrees of maturity, similar to the Georgia shipments, except that the most mature fruit was mellow when stored. This fruit was grown at an elevation of 450 feet on trees six years old. It was medium in size, firm, highly colored, and of excellent shipping quality. Equal quantities were wrapped in California fruit paper and left unwrapped, and packed in the Connecticut half-bushel basket, in Georgia carriers, and in flat, 20-pound boxes, holding two layers of fruit. The peaches were forwarded by trolley to the storage house, which was reached in two hours after the fruit left the packing shed. Duplicate lots of all the series were stored in temperatures of 32°, 36°, and 40° F.

GENERAL STATEMENT OF RESULTS.

The general outcome of the experiments, both with the Georgia and the Connecticut fruit, is similar and may be summed up as follows:

The fruit that was highly colored and firm when it entered the storage house kept in prime commercial condition for two to three weeks in a temperature of 32° F. The quality was retained and the fruit stood up two or three days after removal from the storage house, the length of its durability depending on the condition of the weather when it was removed. After three weeks in storage the quality of the fruit deteriorated, though the peaches continued firm and bright in appearance for a month, and retained the normal color of the flesh two or three days after removal. If the fruit was mellow when it entered the storage house it deteriorated more quickly, both while in storage and after withdrawal. If unripe it shriveled considerably.

In a temperature of 40° F. the ripening processes progressed rapidly, and the flesh began to turn brown in color after a week or ten days in storage. The fruit also deteriorated much more quickly after removal, as it was already nearer the end of its life history. It began to lose in quality at the end of a week.

In a temperature of 36° F. the fruit ripened more rapidly than in 32°, and more slowly than in 40° F. It reached its profitable commercial limit in ten days to two weeks, when the quality began to deteriorate, and after this period the flesh began to discolor. (See Pl. I, frontispiece.

The fruit kept well in all of the packages in a temperature of 32° F. for about two weeks, after which that in the open baskets and in the Georgia carriers began to show wilting. In the 20-pound boxes, in which the circulation of air is restricted, the fruit remained firm throughout the storage season.

It is necessary that the fruit be packed firmly to prevent bruising in transit, but if the peaches pressed against each other unduly it was found that the compressed parts of the flesh discolored after a week in storage. A wrapper proved a great protection against this trouble, especially in the baskets of the Georgia peach carrier, and in all of the packages the wrapped fruit retained its firmness and brightness for a longer time than that left without wrappers.

The fruit should be removed from storage while it is still firm and bright. The peach normally deteriorates quickly after it reaches maturity, and the rapidity of deterioration is influenced by the nature of the variety, by the degree of ripeness when removed, and by the temperature into which it is taken. A quick ripening sort, like Champion, is more active biologically and chemically than the Elberta variety, and the warmer the temperature in which either is placed the sooner decomposition is accomplished. It is advisable therefore to remove the fruit while firm and keep it in the coolest possible temperature.

The peaches in the top of a refrigerator car that has been several days in transit in hot weather are sometimes overripe and need to be sold as soon as the market is reached, while at the same time the fruit in the bottom layers may still be firm. The rapidity with which the fruit cools down in the car depends on the care with which the car is iced, and on the temperature at which the fruit enters the car. Fruit that is loaded in the middle of a hot day and that has been picked in a heated condition may be 20 or more degrees warmer than fruit picked and loaded in the cool of the morning. Such warm fruit ripens much more rapidly, consumes more ice in cooling down, and takes longer to reach a low temperature. When the temperature in the top of the car is higher than that of the lower part the ripening of the upper layers of fruit will be hastened. If the fruit is destined for cold storage, these upper layers, if more mature, should be piled separately, and sold as soon as their condition warrants it. Under these conditions if the fruit from this position is mixed in with the rest of the load it may begin to deteriorate before the remainder of the fruit shows mellowing.

The general principles outlined in former pages for the handling of the Bartlett pear apply to the storage of the peach, except that the latter fruit is more delicate and the ripening processes are even more rapid. Every condition, therefore, surrounding the peach in the orchard, in transit, in the storage house, and at withdrawal must be most favorable. The fruit must be well-grown and well-colored but firm when picked. The packing must be done with care to prevent bruising. If the fruit is to be transported in refrigerator cars, it should be loaded soon after picking, and preferably before it loses the cool night temperature. The peaches should be transferred from the cars to the storage house, or from the orchard to the storage house if the latter is near the orchard, in the quickest possible time. The air of the storage room should be kept sweet and pure. The fruit should always be removed to the coolest possible temperature, usually at the end of two weeks, while it is still firm, and it should be placed in the consumer's hands at once.

If the fruit is overripe when picked, or becomes mellow from unfavorable handling before it enters the storage house, it is already in a critical condition and may be expected to deteriorate quickly.

If the conditions outlined are observed in the handling of the peach, it is possible to store it temporarily with favorable results.

PLATES.

DESCRIPTION OF PLATES.

Plate I. (Frontispiece.) Average condition of Georgia Elberta peaches two weeks in storage after forty-eight hours' withdrawal to a warm room. The upper specimen represents the average condition of fruit stored in a temperature of 36° F. The lower specimen represents the average condition of the fruit stored in 32° F. The lower temperature gave better results in every respect. (Natural size.)

Plate II. Average condition of Maryland Kieffer pears, March, 1902. This fruit was picked from young trees on October 21, 1901, and was stored the following day in a temperature of 32° F. Under these conditions the fruit kept well until late in the spring. (Reduced one-fifth.)

Plate III. Average condition of Maryland Kieffer pears on January 15, 1902. This fruit was picked from young trees October 21, 1901, and stored in a firm condition ten days later in a temperature of 32° F. The delay in the storage caused the fruit to decay from the core outward. (Reduced one-fifth.)

Plate IV. Fig. 1 shows the influence of immediate and delayed storage on Maryland Kieffer pears. The fruit in the box at the right represents the average condition of pears picked October 21, 1901, stored October 22, and withdrawn March 3, 1902. Storage temperature 32° F. The fruit was wrapped in parchment paper. It was in prime commercial condition when withdrawn from storage. The fruit in the box at the left represents the average condition of pears picked from the same trees at the same time. It was stored in the same temperature ten days later and withdrawn March 3, 1902. All of the fruit had decayed. Fig. 2 shows the influence of 36° and 32° F. storage temperature on the keeping of Kieffer pears. The fruit in both packages was picked October 21, 1901, and stored October 22, 1901. The package at the left represents the average condition of the fruit when withdrawn March 3, 1902, from a temperature of 36° F. All of the pears were soft and discolored, and some of them decayed. The fruit in the package at the right, kept in a temperature of 32° F., was bright yellow, firm, and in prime commercial condition.

Plate V. Average condition of Maryland Kieffer pears March 3, 1902. Picked October 21, 1901; stored October 22, 1901. Temperature 36° F. In this temperature the fruit did not keep well after December 1. (Reduced one-fifth.)

Plate VI. The upper figure shows the average condition of western New York Bartlett pears in the center of a barrel one week after being placed in storage. In this position the fruit cools more slowly than that near the staves or ends and it therefore ripens considerably before the temperature is reduced. The lower figure shows the average condition of the pears one week after storing at top and bottom and next to the staves of the same barrel. In these positions the fruit cools quickly and the ripening processes are retarded. For quick ripening fruits that are handled in hot weather small packages are preferable. (Natural size.)

Plate VII. Illustration of the influence of wrappers on the keeping of the Kieffer pear. This fruit was picked October 21, 1901, stored October 22, 1901, in a temperature of 32° F., and withdrawn January 20, 1902. Nearly 50 per cent of the unwrapped fruit was decayed, while there was no loss in the fruit wrapped in news paper or in parchment paper (lowest figure).

KIEFFER PEAR, MARCH, 1902. (FRUIT PICKED OCTOBER 21, 1901, AND PLACED IN STORAGE THE FOLLOWING DAY AT A TEMPERATURE OF 32° F.) REDUCED ONE-FIFTH.

KIEFFER PEAR, JANUARY, 1902. (FRUIT PICKED OCTOBER 21, 1901, AND PLACED IN STORAGE TEN DAYS LATER AT A TEMPERATURE OF 32° F.) REDUCED ONE-FIFTH.

FIG. 1.—WRAPPED KIEFFER PEARS, REMOVED FROM COLD STORAGE (32° F.) ON MARCH 3, 1902

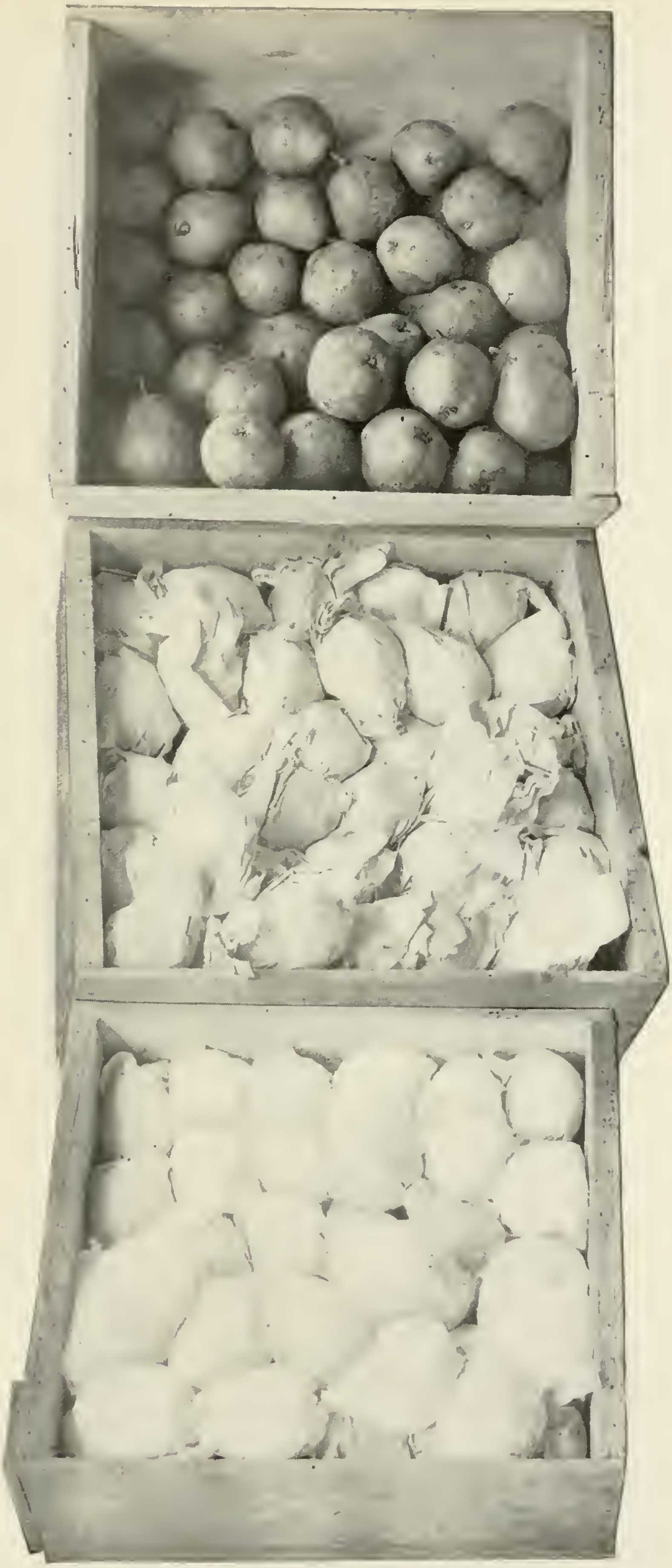
Fruit in both boxes picked October 21, 1901, that on the right being placed in storage on the following day, while that on the left was not stored for ten days.

FIG. 2.—WRAPPED KIEFFER PEARS, REMOVED FROM COLD STORAGE (36° AND 32° F.) ON MARCH 3, 1902.

Fruit in both boxes picked October 21, 1901, and stored on the following day, that on the right at a temperature of 32° and that on the left at 36° F.

KIEFFER PEARS, MARCH, 1902. (FRUIT PICKED OCTOBER 21, 1901, AND STORED ON THE FOLLOWING DAY AT A TEMPERATURE OF 36° F.) REDUCED ONE-FIFTH.

BARTLETT PEARS, ONE WEEK AFTER BEING PLACED IN COLD STORAGE. (THE UPPER FIGURE SHOWS THE AVERAGE CONDITION OF THE FRUIT IN CENTER OF BARREL; THE LOWER FIGURE THAT NEAR THE OUTSIDE OF THE BARREL.) NATURAL SIZE



KIEFFER PEARS, REMOVED FROM COLD STORAGE ON JANUARY 20, 1902.

Fruit picked October 21, 1901, and placed in storage on the following day. Nearly 50 per cent of the unwrapped fruit decayed, while that in parchment wrappers (lowest figure) and in unprinted newspaper kept in perfect condition.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN No. 41.

B. T. GALLOWAY, *Chief of Bureau.*

THE COMMERCIAL GRADING OF CORN.

BY

CARL S. SCOFIELD,

EXPERT, GRAIN INVESTIGATIONS.

BOTANICAL INVESTIGATIONS AND EXPERIMENTS

ISSUED JUNE 13, 1903.

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1903.

BULLETINS OF THE BUREAU OF PLANT INDUSTRY.

The Bureau of Plant Industry, which was organized July 1, 1901, includes Vegetable Pathological and Physiological Investigations, Botanical Investigations and Experiments, Grass and Forage Plant Investigations, Pomological Investigations, and Experimental Gardens and Grounds, all of which were formerly separate Divisions, and also Seed and Plant Introduction and Distribution, the Arlington Experimental Farm, Tea Culture Investigations, and Domestic Sugar Investigations.

Beginning with the date of organization of the Bureau, the several series of Bulletins of the various Divisions were discontinued, and all are now published as one series of the Bureau. A list of the Bulletins issued in the present series follows.

Attention is directed to the fact that "the serial, scientific, and technical publications of the United States Department of Agriculture are not for general distribution. All copies not required for official use are by law turned over to the Superintendent of Documents, who is empowered to sell them at cost." All applications for such publications should, therefore, be made to the Superintendent of Documents, Union Building, Washington, D. C.

No. 1. The Relation of Lime and Magnesia to Plant Growth. I. Liming of Soils from a Physiological Standpoint. II. Experimental Study of the Relation of Lime and Magnesia to Plant Growth. 1901. Price, 10 cents.

No. 2. Spermatogenesis and Fecundation of Zamia. 1901. Price, 20 cents.

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No. 5. Seeds and Plants Imported Through the Section of Seed and Plant Introduction for Distribution in Cooperation with the Agricultural Experiment Stations. Inventory No. 9, Numbers 4351–5500. 1902. Price, 10 cents.

No. 6. A List of American Varieties of Peppers. 1902. Price, 10 cents.

No. 7. The Algerian Durum Wheats: A Classified List, with Descriptions. 1902. Price, 15 cents.

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No. 10. Records of Seed Distribution and Cooperative Experiments with Grasses and Forage Plants. 1902. Price, 10 cents.

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No. 12. Stock Ranges of Northwestern California. Notes on the Grasses and Forage Plants and Range Conditions. 1902. Price, 15 cents.

No. 13. Experiments in Range Improvements in Central Texas. 1902. Price, 10 cents.

No. 14. The Decay of Timber and Methods of Preventing It. 1902. Price, 55 cents.

No. 15. Forage Conditions on the Northern Border of the Great Basin, Being a Report upon Investigations Made During July and August, 1901, in the Region Between Winnemucca, Nevada, and Ontario, Oregon. 1902. Price, 15 cents.

No. 16. A Preliminary Study of the Germination of the Spores of Agaricus Campestris and Other Basidiomycetous Fungi. 1902. Price, 10 cents.

No. 17. Some Diseases of the Cowpea: I. The Wilt Disease of the Cowpea and Its Control. II. A Cowpea Resistant to Root Knot (Heterodera Radicicola). 1902. Price, 10 cents.

No. 18. Observations on the Mosaic Disease of Tobacco. 1902. Price, 15 cents.

No. 19. Kentucky Bluegrass Seed: Harvesting, Curing, and Cleaning. 1902. Price, 10 cents.

No. 20. Manufacture of Semolina and Macaroni. 1902. Price, 15 cents.

No. 21. List of American Varieties of Vegetables for the Years 1901 and 1902. 1903. Price, 35 cents.

[Continued on p. 3 of cover.]

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN No. 41.

B. T. GALLOWAY, *Chief of Bureau.*

THE COMMERCIAL GRADING OF CORN.

BY

CARL S. SCOFIELD,
Expert, Grain Investigations.

BOTANICAL INVESTIGATIONS AND EXPERIMENTS.

Issued June 13, 1903.

WASHINGTON:
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1903.

BUREAU OF PLANT INDUSTRY.

B. T. Galloway, *Chief of Bureau.*

BOTANICAL INVESTIGATIONS AND EXPERIMENTS.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., May 11, 1903.

Sir: I have the honor to transmit herewith, and to recommend for publication as Bulletin No. 41 of the series of this Bureau, the accompanying paper entitled "The Commercial Grading of Corn." This paper was prepared by Mr. Carl S. Scofield, an expert of this Bureau, and has been submitted by the Botanist with a view to publication.

The four half-tone illustrations are essential for the purposes of this bulletin.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

For the past two years the Department of Agriculture has been investigating, in cooperation with the chief grain inspectors of the country, the systems of grain inspection in use in the various grain markets of the United States, in order to ascertain how these systems might be improved and made more useful to agricultural and commercial interests. The investigation has been prosecuted by Mr. C. S. Scofield under the direction of the Botanist, and the present report, covering the subject of corn, is the first to be presented for publication.

A difference of 2 per cent in the moisture of a shipload of corn may determine whether it will arrive at its destination in a sound condition or be seriously damaged. At present the only means which an inspector uses to determine this difference in moisture is his sense of touch, never aided or corrected by any actual measurement of the moisture.

Upon the request of the Botanist, the Chief of the Bureau of Chemistry conducted a series of moisture-determination experiments upon samples of corn furnished him, and fixed upon a form of apparatus suitable for measuring the moisture content of grain. With this apparatus a large series of moisture determinations has been made in the Botanical Laboratory on samples of corn secured from various markets. Based upon the results of these experiments, this report is now published in order to show to the commercial organizations how their inspection may be made more nearly uniform and how both the buyer and the seller may be benefited through the possession of a more exact description of their goods than can be secured by existing methods.

FREDERICK V. COVILLE,
Botanist.

OFFICE OF THE BOTANIST,
Washington, D. C., May 1, 1903.

CONTENTS.

ILLUSTRATIONS.

THE COMMERCIAL GRADING OF CORN.

INTRODUCTION.

The business of buying and selling grain is one of enormous importance in this country. The production of breadstuffs is not the only thing to be considered in supplying the world with food. It is necessary that the raw material be moved to the points where it is needed and in most cases it must be milled before it is consumed.

The business of moving this grain from producer to manufacturer or consumer has been developed to a high degree. There are in nearly all our larger cities, particularly in those through which grain passes on its way to the consumer, either domestic or foreign, trade organizations whose members deal either wholly or partly in grain. These organizations are important to the producer as well as to the consumer, since they furnish the means for easy communication between the two and tend to prevent acute conditions of scarcity or congestion of material.

These organizations have adopted certain rules of trade which aim to permit their members to transact the largest amount of business with the least expense and friction. They have among other things established rules governing the classification and grading of the grain which they handle and the inspection of it, and providing for its weighing and registration.

These classes and grades of grain have been established to facilitate trade and as far as possible to dispense with the cumbersome method of dealing by sample. In some markets the inspection and grading have been developed to such a degree and work so satisfactorily that grain which is deliverable on contract is never shown by sample. The dealers depend wholly upon the honesty and efficiency of their inspection departments. In other markets this is not the case. The purchases, at least those made for consumption or manufacture in the latter markets, are made on the basis of sample and frequently regardless of the grade assigned by the inspection department.

It is customary for the trade organization in each market to establish for each kind of grain what is known as the "contract grade."

This grade is usually, though not always, the one of which there is the largest quantity handled at that market. Practically all deals made on contract or for future delivery are on the basis of this contract grade, and it is the price of this grade that is given in the market quotations.

The determination of what may or may not be delivered as contract grade or any other grade is left to the inspection department, which acts as arbiter, guided by the general rules or customs of the market.

INSPECTION DEPARTMENTS.

Inspection departments are in most cases managed by the trade organization, independent of any outside control either on the part of the consumer on the one hand or of the producer on the other. However, in five States the grain-inspection departments operating therein are under the control of the State, either through a board of railway and warehouse commissioners or through a special commission.

The question as to how these inspection departments should be controlled is a local one and of relatively small importance. As a rule they are supported by fees for services rendered, and are presumably composed of efficient and disinterested men. What these departments need more than a change in or uniformity of control is a greater uniformity in methods of work and in results. To attain this they must have more adequate equipment. They must have available such apparatus as is necessary to educate the judgment of the inspectors for general work and to determine accurately all cases of doubt or appeal.

The cost of maintaining grain inspection is a small item when the interests involved are considered. The charge varies in different markets from about 25 cents to 75 cents per carload or per 1,000 bushels, or from less than one-quarter of a mill to three-quarters of a mill per bushel. A slight error in judgment on the part of an inspector may make a difference of a grade in any cargo, which, under normal conditions, means a difference of 2 or 3 cents a bushel, while at other times, as in case of a "corner," the difference may be much greater. Thus, while the inspection costs, say, 50 cents, a wrong grading might mean a difference of $25 on a carload. Relatively, therefore, the cost of grain inspection is an inconsiderable item.

GRAIN GRADING.

Reduced to its simplest terms, the inspection and grading of grain consists in the examination of the various lots or cargoes to determine the uniformity of each and the assigning of them to the grades to which they belong. This would obviously be simple enough were the elements considered in grading all easily measured and defined, or were they reasonably distinct; but they are neither. The variations on different lots are frequently so slight that if a line is drawn which is to mark a limit of a grade it is difficult to determine in cases close to this line whether they may be admitted or not. More than this, the qualities considered do not vary uniformly; for example, one lot of grain may be of very high quality in all respects but one, while another may be good in all but some other one point, and still another may be mediocre in all respects. For some purposes the first lot might be worth quite as much as if it had no defect, while for other purposes it would be worth less than the other lots merely on this account. It has therefore been difficult to make rules governing grades or to state grade requirements in a way that is definite and satisfactory. The men who have made these rules and definitions for grades have met this difficulty by resorting to the use of indefinite terms and obscure phrases, leaving the responsibility for their interpretation almost entirely with the inspector.

Following are the rules for grading corn recently recommended by the Chief Grain Inspectors' National Association for adoption by the trade organizations and commissions which control the inspection departments represented by these chiefs:

CORN.

No. 1 Yellow Corn shall be pure yellow corn, sound, plump, dry, sweet, and clean.

No. 2 Yellow Corn shall be 95 per cent yellow corn, dry, sweet, and reasonably clean, but not sufficiently sound or plump for No. 1 Yellow.

No. 3 Yellow Corn shall be 95 per cent yellow corn, reasonably dry, reasonably clean, but not sufficiently sound and dry for No. 2 Yellow.

No. 4 Yellow Corn shall be 95 per cent yellow corn, not fit for a higher grade in consequence of being of poor quality, damp, musty, or dirty.

No Grade Yellow Corn. (See general rule.)

No. 1 Mixed Corn shall be mixed corn, sound, plump, dry, sweet, and clean.

No. 2 Mixed Corn shall be mixed corn, dry, sweet, and reasonably clean, but not sufficiently sound and plump for No. 1 Mixed.

No. 3 Mixed Corn shall be mixed corn, reasonably dry, reasonably clean, but not sufficiently sound and dry for No. 2 Mixed.

No. 4 Mixed Corn shall be mixed corn not fit for a higher grade in consequence of being of poor quality, damp, musty, or dirty.

No Grade Mixed Corn. (See general rule.)

No. 1 White Corn shall be pure white corn, sound, dry, plump, sweet, and clean.

No. 2 White Corn shall be 98 per cent white corn, dry, sweet, reasonably clean, but not sufficiently sound and plump for No. 1 White.

No. 3 White Corn shall be 98 per cent white corn, reasonably dry, reasonably clean, but not sufficiently sound and dry for No. 2 White.

No. 4 White Corn shall be 98 per cent white corn, not fit for a higher grade in consequence of being of poor quality, damp, musty, or dirty.

No Grade White Corn. (See general rule.)

No Grade—General Rule.—All grain of any kind and variety that is wet, hot, or in a heating condition, burned or smoky, contains weevil, or is for any reason unfit for warehousing, shall be classed and graded "No Grade."

These rules are considered as representing the latest commercial ideas on rule making for the grading of corn, and were proposed for the purpose of securing uniformity of work by the various inspection departments.

Except for the percentage of color permissible in each of two of the classes, there is scarcely a term used in stating these grade requirements which does not give great latitude for personal interpretation. The terms "reasonably dry" and "reasonably clean" are too indefinite to stand alone as a basis for accurate work. The clause in grade No. 3 "but not sufficiently sound and dry for No. 2" is not especially lucid when investigation shows that the corresponding clause of grade No. 2 reads "but not sufficiently sound and plump for No. 1," while No. 1 requires that the corn shall be "sound," "dry," and "plump."

Having such indefinite standards to work to and being buffeted about by opposing interests vitally concerned in the decisions which he makes, it does not seem strange that the inspector should sometimes do inconsistent work, nor is it to be wondered at that the grading of similar lots of grain differs in different markets.

It is customary in most markets at the present time for the actual work of grading to be done on the railroad track or at the delivery spout of an elevator by a deputy inspector. This deputy must work rapidly, through all kinds of weather and light, in many cases without supervision, and nearly always without apparatus for deciding doubtful cases or means of having his judgment corrected in case of error. If his decision is not satisfactory to the interested parties, appeal may be taken or reinspection called for; but the deputy seldom knows directly the results of such appeal or reinspection. and still more rarely does he know the reason for the change, if one is made.

In some cases shipments from a market are sampled and the samples kept for a time at the main office of the inspection department, particularly in case of cargoes for export; but these samples are taken and kept more for purposes of identification and certification than to educate or correct the judgment of the deputy inspectors.

The movement of grain from one market to another in this country and from the various interior points to the coast ports for export involves, in the regular course of business, unless it is shipped directly through with its identity preserved, from three to six inspections on any given lot of grain. Where grain is handled wholly in bulk and where it must be transferred from cars to elevators, from elevators to boats, from boats to elevators, and again to cars, and possibly again to elevators before being finally delivered for manufacture or export, preserving its identity involves so much additional trouble and expense that it is not ordinarily done; nor would this be necessary were it possible to maintain a system of inspection and grading by which commercial grain could be accurately graded according to its commercial value.

Millers and other manufacturers of cereal products, as well as large consumers of raw cereals, are forced by competition to learn the relative values of the various lots of grain offered for sale. Science has aided these men in determining the best kinds of grain for their various purposes and how they may be distinguished. These manufacturers and consumers are the men who actually and finally determine relative values in cereals, and the discriminations which they make and the elements which they consider in selecting their material should be the basis used by the grain inspectors in their work.

All grain is intended ultimately for consumption, and the number of times it may be bought and sold between the time of its production and consumption makes no change in this fact. The apprehension that uniform or accurate grading of grain may in any way interfere with extensive grain dealing, either actual or speculative, is entirely without foundation. On the other hand, such grading should help the trade by eliminating in a great measure one of the largest sources of misunderstanding and consequent loss, and would give to those who maintain such a system a decided advantage in the world's markets over those who do not.

DEFINITE GRADE STANDARDS.

One of the first needs of the grain trade in this country is to have the grade requirements accurately stated and the grade limits accurately defined. Grain grades, if they mean anything, mean definite relative values.

The chief trouble at present with this grading work is that the inspectors who have to pass upon and accept or reject the grain delivered for a certain grade have no definite standard for guidance—no means of knowing what the grade requirements really are. They have in most cases only their unaided judgment. An appeal from this judgment must go to a board of appeals or to the grain committee controlling the inspection department. In either case the deputy inspector has insufficient opportunity for checking up his work.

In view of the difficulties under which it is done, it is remarkable that the work of the various inspection departments in the commercial grading of grain is not even less successful and satisfactory than is now the case. Without favorable opportunities for educating their judgment, inspectors have nevertheless developed marked ability for determining both quality and condition of grain by actual commercial experience. As the inspector has almost no definite guide for his work, but must use his own unaided judgment, he should not be too severely criticized if the character of his work fluctuates from time to time, particularly since, as has already been stated, he is often called upon to pass his judgment very hurriedly and under adverse conditions of weather and light. In cases where grain is inspected and graded into elevators or for sale on track, an inspector, even one having definitely in mind the supposed grade requirements, is often tempted to let a poor car into a grade if he knows there are some very good cars of that grade going in with it to even matters up. This, of course, works an injustice to the original shippers of the good cars, since the purchaser of the mixed lot can pay no more than the mixture is worth.

GRADE UNIFORMITY.

Our interstate or intermarket trade, as well as our foreign trade, urgently demands a system of grading which shall be uniform throughout the country, or at least for those markets handling the same kinds of grain. In fact, uniformity is at present of more commercial importance than any other one thing connected with grain inspection. This much-desired uniformity can not be attained until there is in use some definite understanding as to what essential qualities shall be considered in the grading of grain, and some definite rules adopted for measuring these qualities.

It is the purpose of this publication, in discussing the commercial grading of corn, to show what some of these essential elements are, something of their relative importance, how they may be measured simply, accurately, and speedily, and how the results may be stated in a way to show exact conditions. These results are expressed in figures, and the promulgation of satisfactory grade limitations is all that remains to secure uniform work, so far as the elements measured are concerned.

The late Mr. S. H. Stevens, the veteran flax inspector of the Chicago Board of Trade, developed such a method for his work, which is probably at the present time the most nearly satisfactory system of commercial grain inspection in existence.

In a report to the Chicago Board of Trade, under date of September 1, 1900, Mr. Stevens published the grade standards for flax adopted by the Board of Trade a year previous, with the statements that during the year of the operation of the definite rules "no suggestion of weakness or desired change has reached this office from any source," and "the flaxseed inspection committee, although in close touch with the department, has not been officially called for the correction of error during the year."

Following is the rule for the grade of No. 1 Northwestern flaxseed published by Mr. Stevens September 1, 1900:

No. 1 Northwestern flaxseed.—Flaxseed to grade Number One Northwestern shall be mature, sound, dry, and sweet. It shall be northern grown or have the usual characteristics thereof. *The maximum quantity of field, stack, storage, or other damaged seed intermixed shall not exceed twelve and one-half per cent.* The minimum weight shall be fifty-one (51) pounds to the measured bushel. [a]

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[a] The italics in the above rule do not occur in the original.

In this connection it is interesting to look at the rules in force under the Minnesota system of grain inspection just before and just after the publication of Mr. Stevens's report.

From Minnesota Grades, August 22, 1900:

No. 1 Northwestern flaxseed.—Flaxseed that is choice or prime, as also the same *moderately intermixed with field damaged seed*, dry, sweet, and free from mustiness, and having weight of not less than fifty pounds to the measured bushel of commercially pure seed, shall be No. 1 Northwestern flaxseed. [a]

From Minnesota Grades, August 31, 1901:

No. 1 Northwestern flaxseed.—Flaxseed to grade No. 1 Northwestern shall be mature, sound, dry, and sweet. It shall be northern grown. *The maximum quantity of field, stack, storage, or other damaged seed intermixed shall not exceed twelve and one-half* ($12\frac{1}{2}$) *per cent.* The minimum weight shall be fifty-one (51) pounds to the measured bushel of commercially pure seed. [a]

The investigations which have been made by the Department of Agriculture during the year past give good reason for believing that what has been found possible in flax is also possible for the cereal grains—corn, wheat, oats, barley, and rye.

It must be distinctly understood that the methods here outlined are not intended to be applied to every car or cargo of grain inspected. The rapidity with which the grain business is conducted makes it impracticable to use any method that requires any considerable time for each lot of grain. These methods, however, may be used as a check upon the work of the deputy inspectors, to educate their judgment, to prevent carelessness or dishonesty, and to give inspection departments a means of justifying the decisions which they make.

ESSENTIAL ELEMENTS IN GRADING CORN.

In grading commercial corn there are two classes of elements to be considered. First, those which indicate condition—moisture, percentage of moldy, rotten, or otherwise damaged kernels, and percentage of broken grains, dirt, and other foreign material; and second, those which indicate quality—color, plumpness, relative proportion of starchy to hard material, and relative size of germ. For present purposes there are four elements which are essential in determining the grade of a cargo of corn and which may, when necessary, be measured with reasonable accuracy and speed. These are (1) the moisture, (2) the percentage of colors in mixtures, (3) the percentage of damaged grains, and (4) the percentage of broken grains and dirt.

The relative importance of these elements varies under different conditions and with the different demands which the grain is used to supply. It is not to be understood that the four elements mentioned are all that should be considered in grading corn, but they are at least important and of such a nature that they may be accurately measured;

[a] The italics in the above rules do not occur in the originals.

and having these four generally understood there is available a basis for uniformity which has not up to this time been offered to the trade.

APPARATUS REQUIRED.

The apparatus required for measuring the elements mentioned above is as follows, the prices given being approximate:

One balance, with weights	$33.00
One copper oven, or air-bath	12.00
One centigrade thermometer	1.25
One gas heater[a]	1.00
One metal sieve, with top and bottom	2.35
One coffee or spice mill	1.75
One set of aluminum pans, at 40 cents each, about	4.80
Miscellaneous apparatus	1.00
Total estimated cost	57.15

The balance should be as accurate as possible, since the most important part of the work depends upon results obtained by its use. It should be sensitive to 10 milligrams or less. A very compact and satisfactory balance is shown in Pl. II, fig. 2.

The oven or air-bath (Pl. I) is simply a copper box covered with asbestos, having a large door and with two holes in the top, through one of which the thermometer is suspended. The bath contains a shelf upon which the pans of material may be placed during the drying operation. When an electric heater is used it may be placed inside, under the shelf. When gas is used the heater must be placed underneath the bath, where it is protected by the galvanized-iron box upon which the bath rests.

The thermometer is suspended through one of the holes in the top of the bath by means of a perforated cork in such a way that it may be read without opening the door. The temperature of the bath should be kept at about 102° to 105° C. (215° to 221° F.). This temperature may be readily controlled without any automatic device, as the operator is usually working near the apparatus and can give it his attention at any time.

When only electricity is conveniently available, a small electric heater may be used. The amount of heat may be controlled by means of an adjustable resistance coil outside of the air-bath. This electric heater has proved very satisfactory, and of course claims the advantage of less danger of fire. Wherever gas is available, however, it may be desirable to use it, as the heat thus obtained is rather cheaper and is somewhat more easily regulated.

The sieve used for determining the amount of broken material, dirt, and other foreign matter is a plain metal sieve having 5 strands to the inch. In other words, it is a wire screen having 25 square holes per square inch.

[a]An electric heater, with resistance coil, would cost about $11, bringing the total estimated cost up to $67.15.

The mill for grinding (Pl. II, fig. 1) should be simple and strong and easily taken apart for cleaning. An extra set of burrs is also desirable, so that in case several samples need to be ground in close succession the burrs may be changed before they have warmed enough to heat the corn passing through.

The aluminum pans are 4 inches in diameter and about 1 inch deep and are used for holding the samples during the drying and weighing process.

In addition to the apparatus mentioned, there are also required some few additional articles, such as a brush, forceps, and a smooth spoon or spatula.

METHODS OF DETERMINATION.

The methods of determining the four elements mentioned may be briefly described.

MOISTURE.

For determining the moisture a small sample of corn should be ground into a coarse meal. If the corn is ground too fine it becomes heated during the operation and there is a consequent and irregular loss of moisture. After grinding a definite quantity of the sample, it should be weighed out in one of the aluminum pans. The larger this quantity the less the percentage of error in weighing is likely to be. However, for quick work the sample must not be too large. Twenty or thirty grams has been found a convenient amount to use. This weighed quantity, which for convenience in reckoning should be an even weight, either 20 or 30 grams, is then placed in the air-bath, which has been previously heated to about 102° C. (215° F.). This temperature is slightly above the boiling point of water and will quickly evaporate the moisture, and after subsequent weighing the percentage of loss may be determined. Theoretically the sample should be dried until repeated weighings would show no further decrease in weight, but for practical purposes, where the element of time required for making these determinations is important, a shorter time will suffice. It has been found by numerous experiments that the amount of moisture which a sample of coarsely ground meal will give up during two hours' drying at 102° to 105° C. (215° to 221° F.) is about 1½ per cent less than the total amount of moisture contained, so that for commercial purposes two hours' drying at the above temperature will yield results from which the total moisture can be estimated with sufficient accuracy for general work. It is necessary, however, to extend this time to three hours on days when the atmosphere is especially damp. Whenever immediate results are not absolutely necessary, it is much safer and more satisfactory to dry the sample completely; that is, to dry it until repeated weighings show no further loss. This commonly requires twelve to sixteen hours. After the samples have been dried they should be weighed again with all possible speed, as the meal readily absorbs moisture from the atmosphere upon being removed from the air-bath. It is best in all cases to make duplicate moisture determinations, as errors are likely to be made by even the most careful workman. These duplicates should be made from separate grindings of different portions of the sample. Where the results of the two determinations in the short-time drying differ by more than about 1 per cent a third determination should be made.

COLOR.

The percentage of color may be determined by simply counting out the number of kernels of each color in a fair average sample. At least 500 kernels should be used as a basis of reckoning.

DAMAGED GRAINS.

The percentage of damaged grains is determined by counting out the number in a fair average sample of at least 500 grains and reckoning the percentage of the number present. The damaged grain is considered to include all cob-rotten, bin-burnt, moldy, or otherwise unsound kernels.

BROKEN GRAINS AND DIRT.

This determination should be made on the basis of weights; that is, by weighing out a definite quantity of corn and separating by means of the sieve mentioned above and by subsequent hand picking, all broken grains, meal, dirt, chaff, and foreign material of whatever nature. This determination should be made on a reasonably large sample of corn—at least a kilogram (2.2 pounds). Where large scales are not at hand it is sometimes convenient to use the ordinary chondrometer or brass bucket employed in making the test weight per bushel of wheat, and the siftings and pickings may be weighed on the small balance used for the moisture work, and the percentage reckoned. The 5½-inch chondrometer holds about 1,800 grams (or 4 pounds) of corn.

CLASSES AND GRADES OF CORN.

The bulk of the corn crop of the United States is of the kind known as dent corn. The grain trade recognizes three distinct classes of this kind of corn, based on color. There are, of course, other colors of dent corn, but practically all commercial corn may be classified into "yellow corn," "white corn," and "mixed corn." There is not at present any great degree of uniformity as to what shall constitute the color limits of these classes, but the general opinion seems to be that the following would be satisfactory:

1. Yellow corn; at least 95 per cent yellow.
2. White corn; at least 98 per cent white.
3. Mixed corn; all corn not included above.

Of each of these three classes of corn there are generally made four grade divisions, numbered one, two, three, and four, with the addition of a grade known as "Rejected," or "No grade." These grades are theoretically made on the basis of considering No. 1 as perfectly sound, perfectly clean, and dry enough to carry or store for an indefinite time. As a matter of fact, the grade No. 1 is seldom or never used as a commercial grade of corn. The grade No. 2 is generally allowed to contain a small amount of broken grains and foreign material and a few damaged grains, No. 3 a slightly increased amount, No. 4 a still larger amount, and the name "rejected" or "no grade" is applied to such corn as is unfit by reason of excessive moisture, dirt, or damage, to be admitted into the numbered grades.

The indefiniteness of the rules governing grades has made it difficult to compare grade requirements of different markets, and any changes found desirable from year to year for different conditions of weather and general quality have been made by different interpretations of the rules rather than by definite changes in the rules themselves. If, however, the methods outlined herewith are put into practice it would be possible to so state the grade requirements that they may be comprehended at a glance. For this purpose it is convenient to use a tabular statement like the following for showing the grade limits. This tabular statement is merely a way of showing in a condensed form the grade rules of a certain market for a certain year, that they may be readily comprehended and market standards compared. Assuming that the trade organization of a market adopts fixed limits for the grades recognized by it and publishes these limits in the ordinary rules for grades, these rules could be shown in a tabular statement something like the following:

DENT CORN.

Three classes:

1. Yellow corn; at least 95 per cent yellow.
2. White corn; at least 98 per cent white.
3. Mixed corn; all corn not included above.

YELLOW CORN.

Grade No.	Maximum limits of—			
	Per cent of moisture.		Per cent damaged.	Per cent of dirt and broken grains.
	Nov.–Mar.	Apr.–Oct.		
1	13	12	0	0
2	15	14	1	2
3	17	16	3	3
4	19	18	6	5

A similar table might be made for each of the other classes of corn, providing different percentages were used.

It should be distinctly understood that the grade limits in the above table are given merely for the purpose of illustrating its use. Just what these standards should be must be determined to suit local conditions or to suit the requirements of each market or series of markets handling the same sort of grain, and they could be changed from year to year as occasion required.

INSPECTION CERTIFICATES.

It is difficult to fix the grade limitations in a way to do full justice to all cargoes graded. Were it possible to assign definite relative values to each measured element a score card could be made by which the cargoes could be rated, but the variety of uses to which any grain is put, results in a sliding scale of relative values, which renders the use of a general score card impossible. Definite grade limitations are absolutely necessary to secure uniform results. To compensate to some extent the injustice sometimes done by drawing sharp grade lines, it would seem desirable to have the inspection certificates show something more than the grade actually given to any cargo of grain.

Such a certificate could show, in addition to the class and grade number of the cargo, its approximate condition as to moisture, damaged grain, broken grains, and, in case of mixture, the proportion of the colors present. A certificate of this kind would enable the prospective purchaser to select, in buying cargoes of grain, those which he could mix to advantage to secure certain results, or a seller might use such a certificate in placing his grain to advantage with customers having particular needs or special facilities for remedying certain defects. These certificates would in no way interfere with the maintenance of the present contract grades and might be of considerable assistance in dispensing with sample dealing.

THE CAUSE OF DETERIORATION.

With the exception of the rather infrequent cases of insect damage of one sort or another, the one cause of the deterioration of corn in transit and storage in this country is excessive moisture.

Corn matures so late in the season over most of the area that produces a surplus, that there is not sufficient warm, dry weather to properly cure it, and the bulk of the crop usually goes into the crib damp and cold.

If it is shelled in this condition and put into store in large bins the grain has almost no opportunity to dry out properly. As long as the cold weather lasts the damage is slight, unless fermentation is accidentally started or the grain is unusually damp, but with the warm weather of spring the trouble begins. In the commercial world this trying time is known as the "germinating season." As a matter of fact, there is little or no actual germination of the stored corn at this time. It rarely develops as far as that. Some fermentative action takes place, equivalent to the preliminary stages of germination, but this usually results in stored grain in the development of sufficient heat to kill the germ.

Under ordinary conditions corn containing not more than 12 to 13 per cent of moisture at the beginning of the warm weather following its maturity will carry or store safely, but new corn, that is, corn soon after maturity, frequently contains 20 to 22 per cent of moisture, and if not given opportunity to dry out during the winter, trouble will result when warm weather comes and induces fermentation.

When corn is left on the cob until the late winter or spring following its maturity, and is stored meanwhile in well-ventilated cribs, it will in most cases dry out sufficiently. But where earlier marketing is necessary other ways of curing must be had if the corn is to be carried safely through the spring season.

There are three things essential to germination or the fermentation which precedes it—air, warmth, and moisture. Without all of these it can not go on.

The moisture is the one of these easiest to control or to remove when it is present in dangerous excess. Therefore when the temperature is nearing the line where the other two elements may result in damage the moisture must be removed. Modern grain storehouses are so constructed that grain may be moved from one bin to another by means of transfer belts and elevators and given a chance to air dry during the moving process. This process is called "running," and is frequently used to keep grain from going out of condition.

In the case of corn, however, this treatment if used too frequently results in breaking many of the kernels and, therefore, damaging the lot to some extent; and the operation is also somewhat expensive where large quantities must be so treated. Within recent years commercial driers of one sort or another have been installed in some of the large warehouses. These driers all depend on the same principle—that is, that an increase in temperature increases the water-holding capacity of the air. In all of them heated air is passed through the corn until the superfluous moisture is removed. This process is known as kiln drying. It is in disfavor with some persons in the trade, who claim that the heat injures the corn for manufacturing purposes, and, further, that the damage by cracking and breaking in subsequent handling of kiln-dried corn is considerable.

There is apparently good reason for some of the disfavor in which the general practice is held, because there has been a tendency on the part of the managers of these driers to work on badly damaged lots of grain and mix the product with better grades.

So far as may be determined at present, the drying of corn at a moderate temperature can be only a beneficial operation. If for certain purposes of manufacture the high temperatures ordinarily used have harmful results, it is quite practicable to use lower temperatures for longer periods or to carry the principle already used still farther and cool the air used for drying to a low temperature to precipitate the excess of moisture it contains and subsequently warm it up enough to make it absorb the excess moisture of the corn.

However it may be done, it is evident that artificial drying of some kind will inevitably be more generally used to prevent the enormous losses now resulting from the excess moisture in corn.

LOCAL AND SPECIAL GRADES.

The development of commercial driers for corn and the specialization in manufacturing cereal products suggests the advisability of keeping in view the possible establishment of additional grades for local and special purposes as needs for them arise. This is particularly important in view of the remarkable work which has been done in improving varieties of corn, not only in increasing the yield per acre, but also in improving the quality; in other words, increasing the percentage of certain desirable constituents. The work that has been done in breeding varieties of corn which have a high percentage of oil and others with a low percentage of oil, and varieties with a high percentage of protein, and others with a high percentage of starch, which means a low percentage of protein, calls attention to the fact that it should be possible for the growers of these improved varieties to get them to those consumers who are willing to pay prices above the ordinary for these extraordinary qualities. It should be the function of the grain inspector to be able to recognize these special classes and to grade the grain accordingly.

It has been shown by Professor Hopkins, of the University of Illinois, that it is possible to judge by observation with reasonable accuracy the merits of different lots of corn as to the amount of protein and oil which they contain. He has shown that, since the oil of corn is found almost entirely in the germ, the relative size of the germ gives a fair indication of the oil content of the grain. Likewise in the matter of protein content, the hard portion of the corn kernel, that is, the somewhat translucent portion outside the germ, contains practically all the protein except the small amount in the germ. Therefore, the larger the proportion of this hard part of the corn kernel the larger the percentage of protein and consequently the smaller the percentage of starch. Manufacturers of corn grits and meal, where a granular product is desired, find that there is considerable variation in the relative yields of these products from different sorts of corn.

In Pl. III is shown the striking difference that may be seen in different kernels of corn as to the proportion of the hard and starchy portions of the grain. Other things being equal, the yield of grits or granular meal is larger from corn having the larger proportion of this hard material.

Corn breeders and progressive farmers are rapidly appreciating the importance of breeding special varieties of corn for special purposes, and it is probable that in the near future certain varieties of corn from certain localities will be quite as distinctly recognized as being rich in specific merchantable qualities as is now the case in such varieties of wheat as the Fife, the Little May, or the Mediterranean. This will naturally lead to a more logical classification of commercial corn on the basis of varieties or groups of similar varieties, and these classes may then be divided into grades, as at present. Such a classification would in no way conflict with the present methods of commercial dealing, since the trade organization of a market could determine what grades could be delivered on contract just as is done at present.

The greatest need of the grain trade now, however, is the installation of an accurate method of determining grades in all cases of doubt and for the education of the judgment of the grain inspectors and the consequent uniformity of the work of inspection departments.

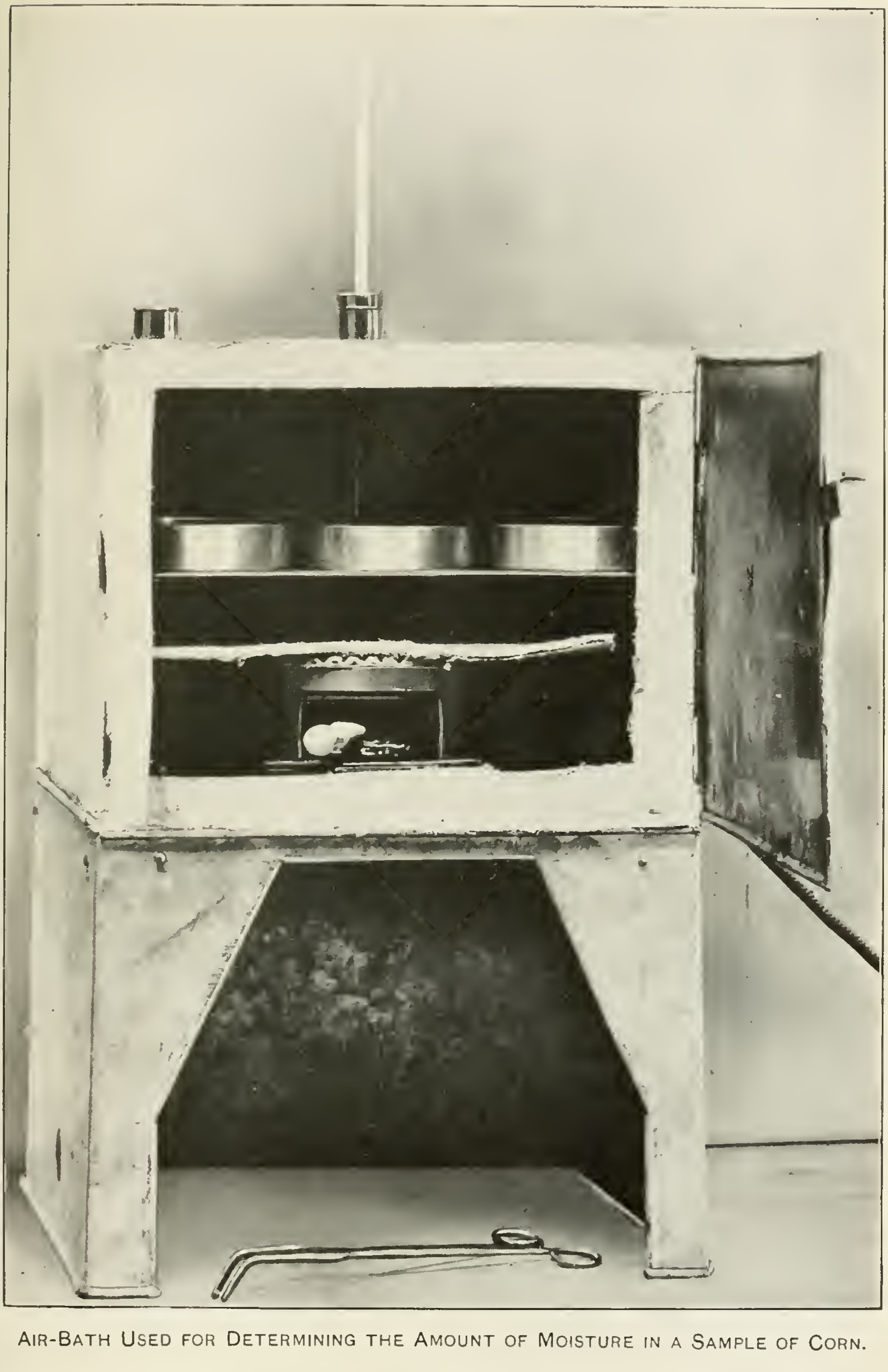
DESCRIPTION OF PLATES.

PLATE I. Air-bath used for determining the amount of moisture in a sample of corn, with aluminum pans and electric heater inside. A piece of asbestos is placed over the heater to distribute the heat more evenly to the pans. The forceps shown below are for transferring the pans to and from the bath to avoid the possible error consequent on touching them with moist hands.

PLATE II. Fig. 1.—Mill for grinding corn samples, with extra set of burrs and brush for cleaning mill after each grinding. This mill may be clamped to the edge of a table and is simple and strong. It may be easily taken apart for cleaning or changing the burrs. Fig. 2.—Balance used for weighing corn samples. This balance is surrounded by a metal frame set with plate glass, and is provided with a sliding weight on a fixed scale, so that the weighing may be done rapidly.

PLATE III. Kernels of corn shown in longitudinal and cross section. Magnified six times. These kernels show rather extreme variations in texture. The two kernels at the left of the picture show a high proportion of the hard or translucent substance of the kernel outside the germ, which has been shown by Professor Hopkins, of the Illinois State Experiment Station, to be directly correlated with high protein content. The kernels on the right show a relatively small amount of this hard substance, and are consequently of the type which is low in protein and therefore rich in starch. For processes of manufacture of corn where a granular product is desired the type of corn shown on the left is much preferred, while for starch manufacture the type shown on the right of the picture is more desirable. In the same way the relative size of the germ of the corn kernel indicates the percentage of oil contained, since practically all the oil of the corn kernel is found in the germ.

PLATE IV. Kernels of corn showing various kinds of damage, and sound kernels shown for comparison. Twice natural size. The upper three rows are of kernels showing the various mold growths commonly found on damaged corn. These molds develop only on excessively moist corn and are much more likely to occur when there is a deposit of fine meal or dirt in the germ indentation. This deposit offers a good culture medium for the development of the molds, and in a majority of cases the damage starts at that point. Perfectly clean corn will carry or store much more safely than dirty corn having the same amount of moisture.



AIR-BATH USED FOR DETERMINING THE AMOUNT OF MOISTURE IN A SAMPLE OF CORN.

FIG. 1.—MILL FOR GRINDING CORN SAMPLES.

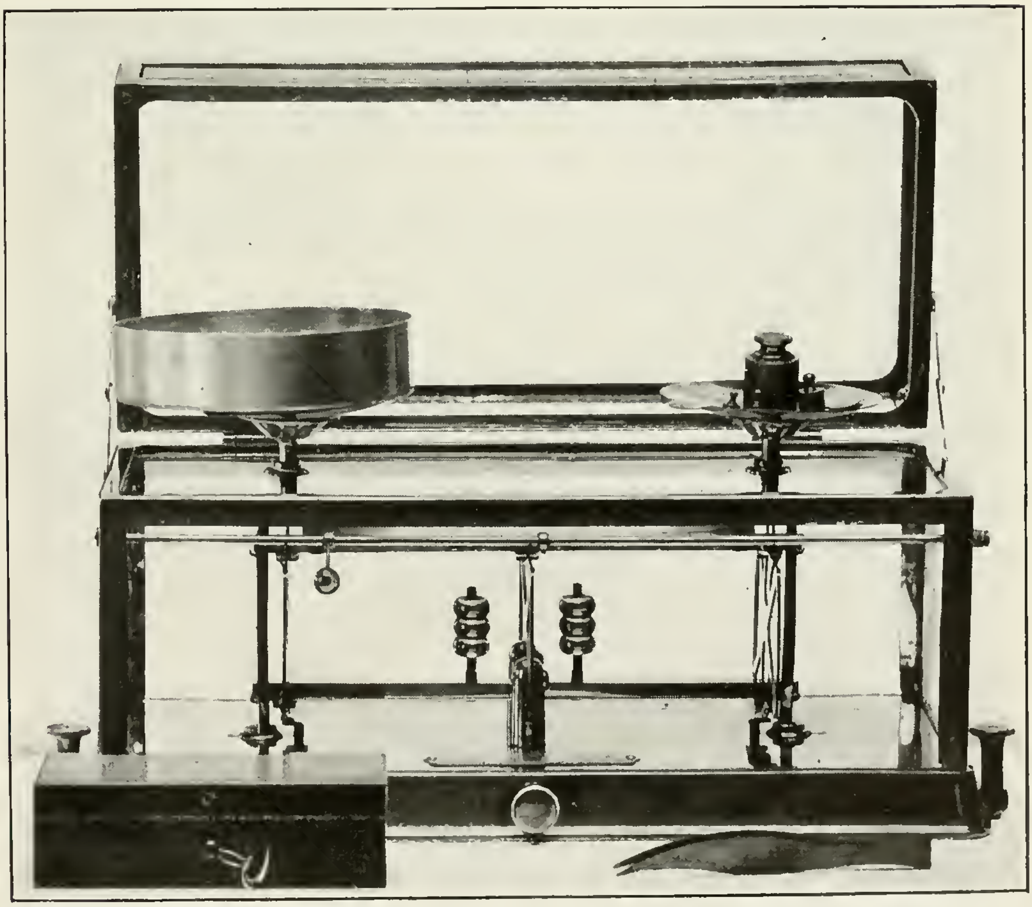
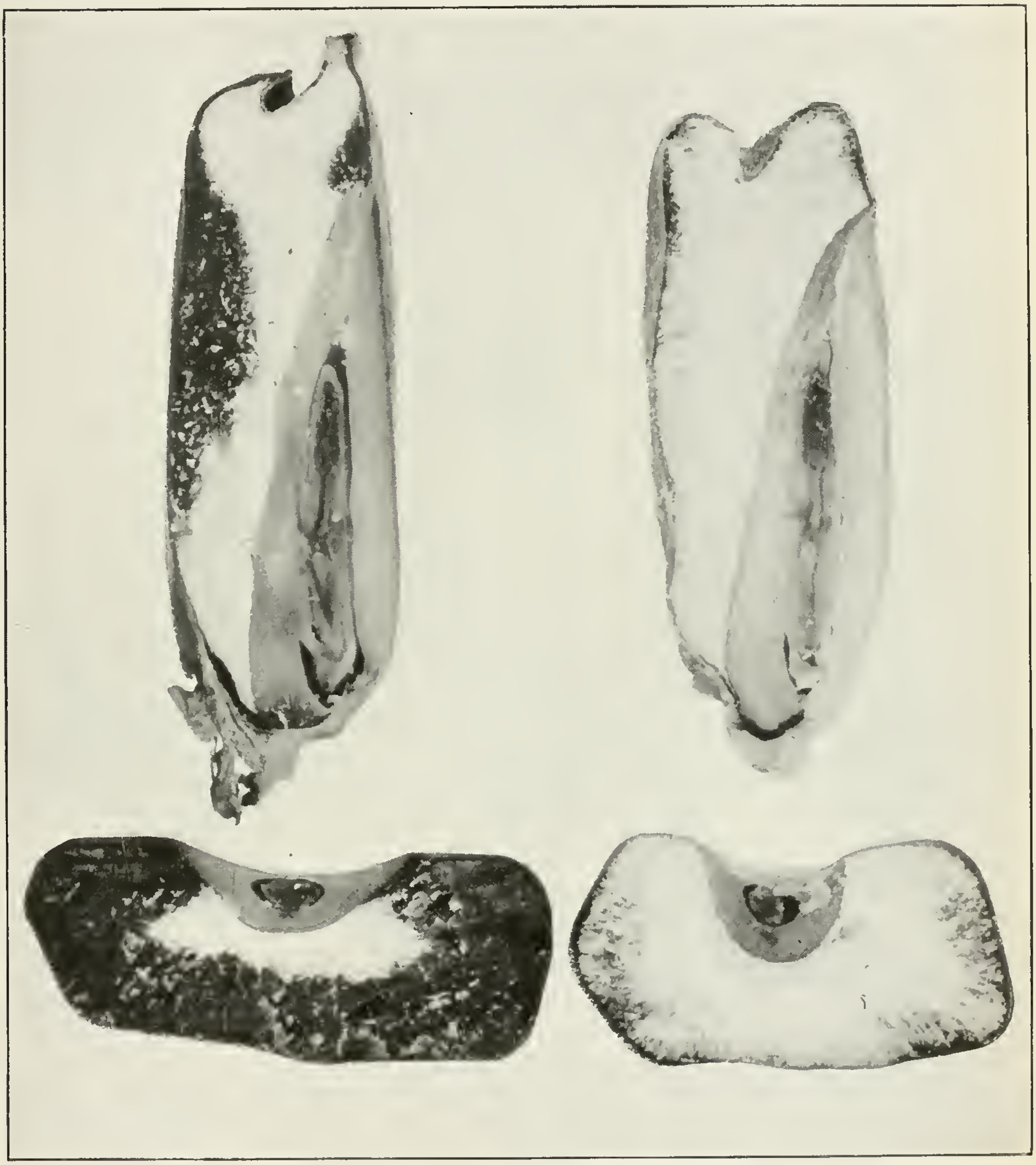
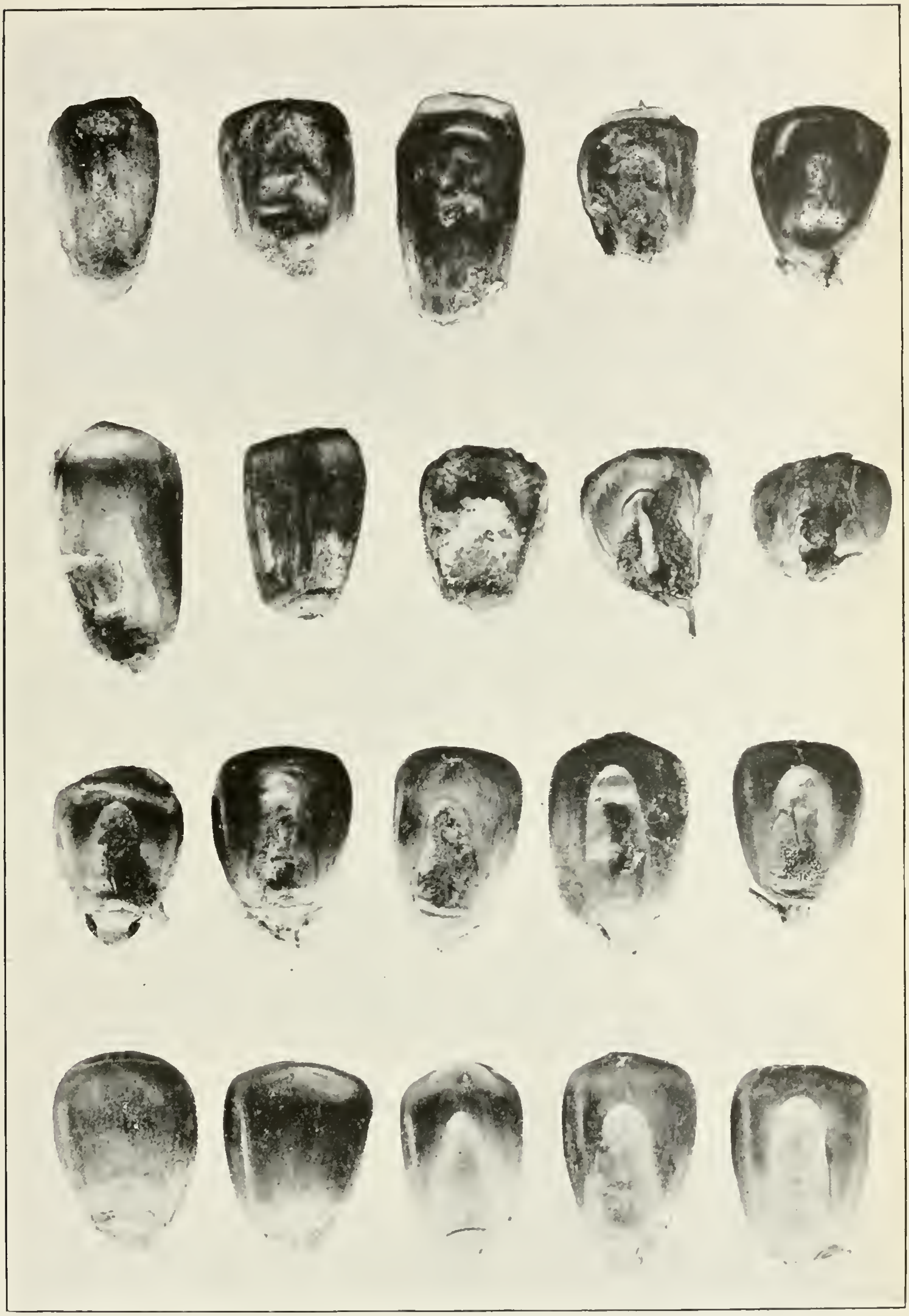


FIG. 2.—BALANCE USED FOR WEIGHING CORN SAMPLES.



KERNELS OF CORN, SHOWN IN LONGITUDINAL AND CROSS SECTIONS.



KERNELS OF CORN, SHOWING VARIOUS KINDS OF DAMAGE.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 42.

B. T. GALLOWAY, *Chief of Bureau.*

THREE NEW PLANT INTRODUCTIONS FROM JAPAN.

BY

DAVID G. FAIRCHILD, Agricultural Explorer.

SEED AND PLANT INTRODUCTION AND DISTRIBUTION.

Issued June 24, 1903.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1903.

BULLETINS OF THE BUREAU OF PLANT INDUSTRY.

The Bureau of Plant Industry, which was organized July 1, 1901, includes Vegetable Pathological and Physiological Investigations, Botanical Investigations and Experiments, Grass and Forage Plant Investigations, Pomological Investigations, and Experimental Gardens and Grounds, all of which were formerly separate Divisions, and also Seed and Plant Introduction and Distribution, the Arlington Experimental Farm, Tea-Culture Investigations, and Domestic Sugar Investigations.

Beginning with the date of organization of the Bureau, the several series of bulletins of the various Divisions were discontinued, and all are now published as one series of the Bureau. A list of the bulletins issued in the present series follows.

Attention is directed to the fact that "the serial, scientific, and technical publications of the United States Department of Agriculture are not for general distribution. All copies not required for official use are by law turned over to the Superintendent of Documents, who is empowered to sell them at cost." All applications for such publications should, therefore, be made to the Superintendent of Documents, Union Building, Washington, D. C.

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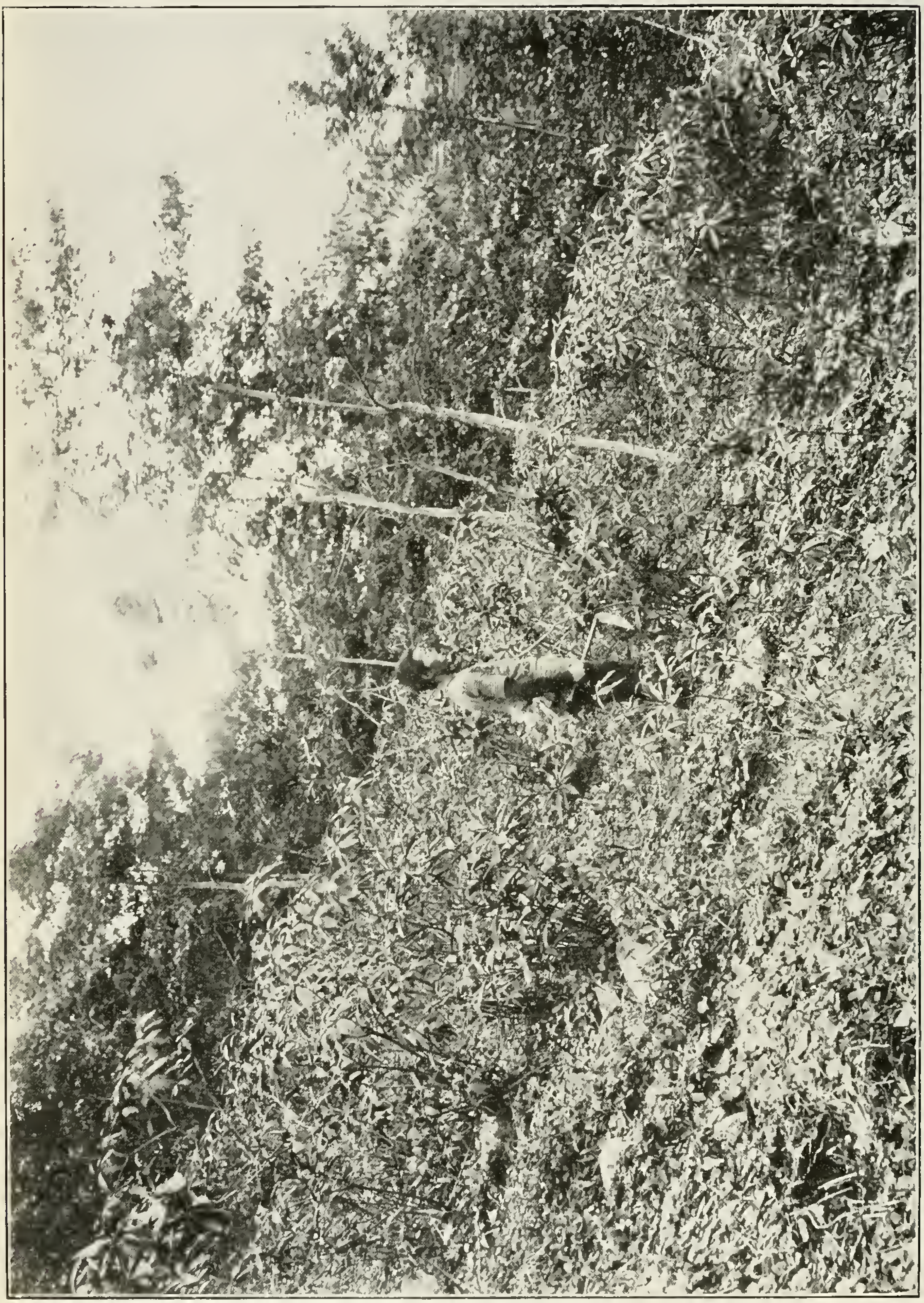
[Continued on p. 3 of cover.]



A HILLSIDE COVERED WITH MITSUMATA, THE JAPANESE PAPER PLANT.

U. S. DEPARTMENT OF AGRICULTURE.

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BUREAU OF PLANT INDUSTRY.

BEVERLY T. GALLOWAY, *Chief of Bureau.*

SEED AND PLANT INTRODUCTION AND DISTRIBUTION.

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GEORGE W. OLIVER, *Expert.*

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., May 13, 1903.

Sir: I have the honor to transmit herewith a paper entitled "Three New Plant Introductions from Japan," and respectfully recommend that it be published as Bulletin No. 42 of this Bureau.

This paper was prepared by Mr. D. G. Fairchild, Agricultural Explorer, who has been detailed by you to accompany Mr. Barbour Lathrop on his expeditions in search of valuable seeds and plants, and it has been submitted by the Botanist in Charge of Seed and Plant Introduction and Distribution, with a view to publication.

The six full-page half-tone illustrations are an essential part of the paper.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

As a result of his observations on the agriculture of Japan, Mr. D. G. Fairchild has contributed several papers designed to interest American cultivators in new crops. Three of these papers are published in this Bulletin. One on a Japanese paper plant calls the attention of farmers in the mild and humid regions of the United States to a possible new industry, while those on the udo and on the Japanese horse-radish will doubtless prove of interest both to market gardeners and amateurs who take pleasure in cultivating the best vegetables.

The plants and seeds received from Mr. Lathrop, through Mr. Fairchild, have been placed for trial with reliable horticulturists, and the results of these tests will enable us in the course of time to report more fully regarding the adaptability of these plants to our conditions.

A. J. Pieters,
Botanist in Charge.

Office of Botanist in Charge of Seed and Plant Introduction and Distribution,
Washington, D. C., May 8, 1903.

CONTENTS.

ILLUSTRATIONS.

THREE NEW PLANT INTRODUCTIONS FROM JAPAN.

MITSUMATA, A JAPANESE PAPER PLANT.

INTRODUCTION.

The facts for this paper were collected during a four months' stay in Japan, and represent work accomplished by Mr. Barbour Lathrop's third expedition in search of valuable seeds and plants.

It is hoped that the introduction of this new Japanese paper plant and its ultimate culture in the warmer parts of the United States will be encouraged by this brief account of its cultivation in Japan, for the production of any of the Japanese bark papers, which are for many purposes much superior to our own, will be a material addition to the wealth of the country and give the cultivators of the South a new crop of value.

Japanese napkins, umbrellas, and lanterns have taught the Occidentals new uses of paper, though the lesson has been but half learned.

The papers employed by the common people of Japan are immeasurably more varied than with us. They form one of the important economies in the life of the peasant, and it is such ingenious uses of plant material as this employment of the bark of a shrub that makes it possible for 42,000,000 Japanese to live on the productions of a cultivated area about one-third the size of the State of Illinois.

The walls of the Japanese houses are wooden frames covered with thin paper which keeps out the wind but lets in the light, and when one compares these paper-walled "doll houses" with the gloomy bamboo cabins of the inhabitants of the island of Java, or the small-windowed huts of our forefathers, he realizes that, without glass and in a rainy climate, these ingenious people have solved in a remarkable way the problem of lighting their dwellings and, at least in a measure, of keeping out the cold.

Their oiled papers are another important element in the peasant life of the Japanese, and are astonishingly cheap and durable. As a cover for his load of tea when a rain storm overtakes him, the Japanese farmer spreads over it a tough, pliable cover of oiled paper, which is almost as impervious as tarpaulin and as light as gossamer. He has doubtless carried this cover for years, neatly packed away somewhere about his cart. The "rikisha" coolies in the large cities wear rain mantles of this oiled paper which cost less than 18 cents and last for a year or more with constant use.

An oiled tissue paper, which is as tough as writing paper, can be had at the stationers for wrapping up delicate articles. Every farmhouse has its stock of wrapping paper which has been in use for several years and seems as strong and flexible as ever. It has been tanned with the fermented juice of green persimmons and made into "shibu gami," which is more impervious to moisture than ordinary paper and much tougher.

In the tea factories, the piles of paper sacks filled with tea are made of shibu gami, and 8-year-old sacks covered with paper patches are a common sight. It is said that these tanned sacks keep the tea in better condition than any other sort, and that they last with careful use for many years. Grain and meal sacks are almost always made of this same paper in Japan, for it is not easily penetrated by weevils and other insects.

But perhaps the most remarkable of all the papers which find a common use in the Japanese household are the leather papers of which the tobacco pouches and pipe cases are made. They are almost as tough as French kid, so translucent that one can nearly see through them, and as pliable and soft as calfskin. These tobacco pouches quite change one's notions of the characteristics of paper, for the material of which they are made is as thick as cardboard, but as flexible as kid. Even woven fabrics of which the warp is paper and the woof cotton are manufactured, and these find a place in the Japanese household, while the use of paper napkins and handkerchiefs, umbrellas, and lanterns is as much a part of home life in Japan as the use of cheap tin articles is in America. The country is rich in the possession of these conveniences, any one of which would be an addition to the comfort of a European peasant or an American farmer. But the reason for this remarkable use of paper articles does not lie wholly in the absence of cheap skins, though it is true that few domesticated leather-producing animals exist in Japan. The quality of the papers themselves makes them suitable, as ours are not, to these various purposes.

In strong contrast with those of the Occident, these are bast papers, made from the inner bark of shrubs or small trees, while the papers of Europe and America are either from wood pulp, the macerated stems of wild grasses, or the cotton and linen rags of the ash barrels. It is not a pleasant thought that the brilliant white note paper which your hand rests upon may have in it the fibers from the filthy garment of some Egyptian fellah after it has passed through all the stages of decay until it is saved by a ragpicker from the gutter of an Egyptian town; and yet it is a fact that hundreds of tons of Egyptian rags are exported every year into America to supply our paper mills. At Mannheim on the Rhine the American importers have their rag-picking houses, where the rags are collected from all over Europe, the disease-infected Levant not excepted, and where women and children, too poor to earn a better living, work day after day, with wet sponges tied over their mouths, sorting these filthy scraps for shipment to New York. Our best papers are made of these rags and our common ones of wood pulp, which is obtained by grinding and macerating huge blocks from some of our soft-wooded forest trees. The bast papers, therefore, are a creation of the Orient and are more nearly related to the South Sea Island tapa than to any of our products.

To the fact that they are made from bark they owe their peculiar character. They are as a rule softer, silkier, tougher, and lighter than our papers. If wet, they lose their strength, like tissue paper, but on drying regain it. They are usually absorbent, and for this reason were considered in the olden days as very valuable in surgery. Whether or not the methods employed in their manufacture are responsible for the yellow tinge which they always have is a question for investigation. As writing papers they are designed for brush work, and as a rule are not suited without treatment for pen work, because the fibers in them are so long that they are continually getting caught in the nibs. This difficulty, however, is obviated by a dressing of alum.

SPECIES OF PAPER PLANTS IN JAPAN.

According to the Japanese writers, there are at least nine plants from which papers are made in Japan, each species furnishing a different variety of product. Two are species of the paper mulberry (*Broussonetia*), one the white mulberry (*Morus alba*), another a species of Daphne (*D. pseudo-mezereum* Gray), three are wild forms of a small tree (*Wickstrœmia*), and one, the *Edgeworthia papyrifera*, furnishes the pulp for the mitsumata paper, of which we import large quantities every year, especially for use as legal documents, diplomas, deeds, bonds, etc.

The main object of the writer is to give a description of the mitsumata plant and its culture, with the purpose of interesting Americans in the question of its cultivation and the manufacture of the extremely useful papers which can be produced from its bark and which deserve to be widely known throughout America.

THE MITSUMATA PLANT.

Edgeworthia papyrifera S. & Z. is the botanical name of the mitsumata paper plant, and the systematists place it, along with the Daphne, among a number of forms with lace-like bark, in the order *Thymelæceæ*. It is a pretty, decorative shrub, with characteristically branching stems, broad, light-green leaves, and delicate yellow flowers which are borne in heads. Its forks are always composed of three branches instead of two, as is common with other shrubs, and this character alone distinguishes it from any common shrub in cultivation. It is sometimes grown in Japan for its decorative yellow flowers alone. The Marquis Matsudaira, formerly one of the feudal lords of the country, has it planted inside his castle walls at Fukui as an ornamental plant. Scarcely over 5 feet high, it has, as a result of its peculiar branching habit, a characteristic vase form. (Pls. I and II, fig. 2.) Owing to the fact that in the cultivation of the plant it is continually pollarded near the surface of the ground, it is difficult to say what the plant would grow into if left to itself. The light, brownish-gray bark is thick and lace-like as a piece of tapa, and one can easily spread a bit of it out with the fingers into a web-like, rough fabric. The small fruits are borne in clusters and are about a quarter of an inch long. Each fruit contains, inside the thin layer of flesh, a shiny black, sharp-pointed seed, with a thin shell and milk-white contents.

In the provinces of Shizuoka, Nogano, and Fattori are quite extensive plantations of mitsumata, and it is said that the areas under cultivation are steadily increasing. As a rule, the plantations occupy land which is not fit for rice growing, such as hillsides too steep for terracing and valleys too narrow to make rice culture practicable.

Red or yellow clay of volcanic origin, mixed often with rocks and coarse gravel, seems to suit the plant admirably. The hillside plantations sometimes reach to the line of newly cut cryptomeria forest, and even cover the tops of the hills from which, many years before, the timber had all been cut. Good drainage seems to be one necessary requisite to the growth of the plant in the wet climate of Japan, but its culture between the rice fields proves that it can stand heavy irrigation, though a plant not well suited to withstand drought.

THE CULTIVATION OF MITSUMATA.

Early in June, in Japan, children not over 8 or 9 years old are sent through the plantations with baskets to pick the ripe fruits of the mitsumata. The plants produce seed sparingly, it is said, so that the work of collection is much like picking wild blackberries or strawberries in America, but it is far more irksome for the children, for instead of being palatable the thin-shelled seeds contain an exceedingly acrid endosperm.

The seeds, with their thin, green flesh, are spread out to weather until the latter has rotted away, leaving the black seeds, which are packed in a sack made from the double sheath of the native palm. The meshes of this natural sack are fine enough to prevent the seeds from falling out and still allow the air and moisture to enter. In this form they are buried in a hole in the ground under the shelter of an overhanging roof or are stored in some outbuilding and kept until planting time the following February. The price of this seed varies greatly; from 30 cents to $1.50 a gallon was the range quoted the writer by the peasants.

In the middle or toward the last of February the seed bed is prepared and the seeds are planted in rows a foot or so apart, where they are given the usual care of weeding and cultivation which all seedlings require, and where they remain for one year, or until 8 or 9 inches high. These young plants are then set out on the hillsides, after the ground has been prepared for their reception by working it over with a mattock or fork. They are put in at the rate of 20,000 to 24,000 to the acre, or about a foot and a half apart each way. On the hillside plantations shelter trees of a species of alder (*Alnus maritima* var. *japonica*) are planted 20 to 30 feet apart. The roots of these trees are said to help bind the loose soil, the dead leaves form a mulch, and the branches form a wind-break, preventing the winds from whipping the young shoots of the mitsumata plants. Two or three cultivations a year are given to keep down the weeds and loosen the soil, and by the end of the first year after transplanting the harvest of bark is ready.

The harvesting is done any time in the winter and consists merely in cutting the plants down to the ground by means of a heavy knife, binding them into bundles, and transporting them to the farmhouse. Though the tops are cut down every other winter, the roots of the mitsumata plants remain alive for many years—roots a hundred years old are known, it is said—but for commercial purposes the stumps of the plant cease to produce profitable crops of new shoots after ten or twelve years, when they are dug out and young plants are set in their places. It requires two years for an old stump to produce a marketable bush, and many of the plants are evidently allowed three or four years to grow before being cut down again.

The crop would naturally be a biennial instead of an annual one, but owing to the fact that some plants have to be replaced earlier than others a field of mitsumata soon has growing on it plants in various stages of maturity, and the cutting can be done every winter.

From 600 to 2,000 pounds of raw bark per acre are produced by this plant, according to a statement made by a paper manufacturer, and when made into pulp it is worth in Japan 15 to 16 cents gold per pound, or four times what the imported wood pulp from America sells for in Yokohama.

The bark is removed from the cut shoots by the peasants, who soak them in hot water and strip off the bark by hand. From the clean appearance of the bundles of peeled branches it seems probable that the bark slips off easily (see Pl. III, fig. 1), leaving light, porous faggots, suitable for kindling wood. Whether or not the bark could be removed by machinery has yet to be investigated, but the soft nature of the wood makes it seem an easy matter to crush the stems and separate the wood from the bark after the crushing. The fact that in Japan these, as well as the other processes, are done by hand signifies little as regards the possibility of the application of machinery, when it is remembered that until two years ago such simple operations as tea firing and sifting were done there—and are yet to a large extent—by hand.

THE MANUFACTURE OF MITSUMATA PAPER.

Small paper factories are scattered along the banks of the picturesque mountain streams in central Japan, and the broad drying boards covered with sheets of fresh paper are common sights in many of the mountain villages. (See Pl. III, fig. 2.)

The freshly stripped bark is macerated in vats of warm water and the thin outer bark is removed by scraping with a dull knife. The purity of the paper depends in large measure upon how thoroughly this dark part is removed, for any small particles that are overlooked in the cleaning make dark flecks in the paper. After cleaning, these soft, spongy strings of bark are thrown into a vat filled with caustic soda, and are left to macerate thoroughly until the fibers can be easily separated from each other. The macerated bark is then pounded, either in a stone mortar with a heavy wooden mallet or by means of a stamping mill run by water power until it is a homogeneous pulp. It is then mixed with water, bleached with chlorid of lime, and put into a large vat, from which small quantities are taken by the hand screens which the operator uses in making the sheets of paper. A mucilage made by macerating the root of a species of hibiscus (*H. manihot*) is added in small quantities to the pulp to make the fibers stick together. The amount of this mucilage used seems to be a matter of experience. One woman can make, by means of her bamboo hand sieve, 600 sheets of paper a day, and, according to the prices given me through an interpreter, this medium quality of paper sells for about 94 cents a hundred sheets. It is very interesting to watch how skillfully the operator lifts from the vat a screen half full of thin pulp, poises it and shakes it for a second or two, allows the water to drain out for a few moments, then quickly lifts the screen and, inverting it, lays it face down on the pile of previously made sheets. She then gently and slowly lifts the sieve and leaves a thin layer of wet pulp upon the continually thickening pile. With a hand press the water is squeezed out of this pile of wet papers, the individual sheets are stripped off one by one, brushed out on smooth boards with brushes just like those used by the paper hanger to spread the paste on wall paper, and are then put out in the sun to dry, after which simple process the papers are packed in bundles and taken by pony or bull pack animals to the nearest market. In at least one town in Japan paper-making machinery is being employed in the manufacture of the finer grades of mitsumata paper for export to America. These machines are rotary, steam-heated drums for macerating the pulp with caustic soda, and the regular pulping tanks for separating the fibers and in which the blanching process is carried on. In the mill which the writer visited the same bamboo hand sieves were employed by the operators in making the sheets from vats of the pulp, so that the papers made by this mill should still be classed as handmade papers.

The laborers at work in separating the inner from the outer bark were getting only 9 to 10 cents gold a day, and it seemed as if the work was so mechanical in nature that it could easily be done by machines; but this question could only be decided by an investigation made by experts in such matters. The question also whether the hand sieves could be done away with and continuous-process machines substituted for them must be settled by repeated trials. Problems which appear much more complicated have been solved by American mechanics.

THE MANUFACTURE OF LEATHER PAPER.

"Tsuboya" paper is a most peculiar looking substance. It resembles oilcloth, but has a texture more nearly resembling that of fine leather, except that it is more or less translucent, like oiled pigskin. In the province of Ise, Japan, are noted manufacturers of tobacco pouches who use only this leather paper in their manufacture, and the variety of styles in which they make their papers is remarkable.

Yamada, where Seibei Ikebe (who is probably the most noted maker) has his shop, is a favorite place for pilgrims, and for several generations Ikebe and others have sold them their paper tobacco pouches until it has become the fashion for every pilgrim to bring back from his pilgrimage to Yamada a paper pouch as a souvenir.

Some of these leather papers are smooth and almost transparent; others are rough and stamped with pretty patterns, a host of different colors being used in their printing. They are in character a kind of wrinkled oiled cardboard and the process of their manufacture is a tedious though comparatively simple one.

A thick, weak cardboard called "onagashi" paper, which is manufactured of bark fiber in one of the interior towns near Gifu, is imported into Yamada in large quantities. Before processing it is soft and tough, but will break like any thin cardboard. To transform it the sheets are moistened and then wrapped about a small round stick the size of a broom handle. Several sheets are wrapped at a time, separated from each other by special dry papers which have been painted with persimmon juice to tan them, and the roll of these papers is finally wrapped with a cloth and tied. This roll, out of both ends of which the stick protrudes, is put under a long lever, one end of the stick being stuck through a hole in the lever and the other lodged in a hole through the floor. The workman then sits on the long end of the lever and teeters until the roll of papers, which was originally about 18 inches long, is reduced to not more than 12 inches. He then removes the roll, undoes it, spreads out the papers, again arranges his dry sheets, and prepares another roll for the lever, inserting the same papers in a different position. Eight times he subjects the papers to this wrinkling process, and each time they become smaller, thicker, and more pliable until, after the last wrinkling, the cardboard is as soft and limp as a bit of muslin.

Once through the wrinkler, the paper is given a coating of oil made from the seed of a labiate (*Perilla ocymoides*) and hung out to dry. For over a hundred days it is hung in the open air to allow the oil to harden, and even two hundred days are sometimes required to finish this part of the process. After being once dried out the piece of wrinkled oil paper can be treated in almost any way—shaved or scraped with a sharp knife, stamped or beaten with dies or patterns, or given a coat of lacquer varnish. If colored papers are required, the pigments are applied before the oiling process.

Although these remarkable papers are used now almost exclusively for tobacco and other pouches, there are other uses to which the inventive American mind can put them, such as book covers, portfolios, table covers, etc., and the writer is of opinion that, should they once be available to the common people, many new and important applications for them would be found.

A similar form of these leather papers is the Japanese handmade wall paper, which is already becoming fashionable in America. Large factories are running near Tokyo which turn out the most beautiful designs for wall and ceiling decoration. These wall papers are wrinkled in the way previously described, though evidently not so finely, and are then stamped and modeled by hand into the most artistic designs imaginable.

The extent of the leather-paper industry is not great, but, as it is, over 200,000 paper pouches are made annually by one firm alone in Yamada and about $15,000 worth of business yearly is claimed to be done by the same firm.

Any plant from which can be produced a set of papers widely different from those we already have is worthy of consideration by the cultivators of the country, and if the processes of manufacture can make out of it better, stronger envelopes, finer and lighter wrapping paper, more suitable toilet papers, or a cheap and useful substitute for leather, the cultivation of the plant in America may prove decidedly profitable.

As the species of mitsumata is not one which will withstand much cold, it is useless to try to grow it in any regions where the thermometer sinks below 10° F., and as it requires moisture there would be no reason for testing it on the dry plains. The irrigated rice fields of Texas, with their unoccupied dikes and narrow strips of land between the fields, would form excellent trial places for the plant, and the Colorado Desert, with its rich soil and abundant water supply, might prove well adapted to its cultivation. The moister portions of Florida and Louisiana could be used for experimental cultivation, and the irrigated regions of the Sacramento and San Joaquin rivers would probably be suitable for the growth of this Japanese paper plant.

UDO, A NEW WINTER SALAD.

INTRODUCTION.

Nothing has yet been found which competes with lettuce for the first place as a winter salad, but for a change there are so few salad plants which can be had in the winter that a new and eligible one is surely worthy the serious attention of the public.

Udo is a plant which has been in cultivation for many years in Japan, and was probably introduced from China, where it is known as a vegetable under the name of t'u-tang-kuei, according to Dr. Augustine Henry in his notes on the Economic Botany of China.

In the tea houses all over Japan its crisp, blanched stems are served fresh with salt or boiled with a soy sauce. Eaten as served by the Japanese, it would not be likely to attract the attention even of one in search of such things except as being the best of the collection of those characteristic dishes which form the menu of a Japanese meal.

To Miss Fanny Eldredge, of Yokohama, belongs the credit of having first adapted this udo to the requirements of the Western table, and it was at the home of Mrs. Stuart Eldredge that the attention of Mr. Lathrop was first called to this novelty in winter salads. Even old residents in Japan are unfamiliar with this truly delicious vegetable.

As served in Western style, udo is a mass of thick white shavings, 2 to 3 inches long by a half inch wide, with a brilliant, silky luster. Miss Eldredge has found that the best dressing is a French one of oil, vinegar, salt, and pepper, and her method of preparation is to cut the shoots into long, thin shavings and allow these to stand in ice water for several hours before putting them into the salad bowl and pouring over them the French dressing prepared in the usual way.[a]

These slices of udo are crisper than slices of celery and have none of the objectionable stringy fibers of the latter. They have a fresh

[a] The recipe for the dressing is as follows: For one salad bowl of udo, take one tablespoonful of vinegar, one teaspoonful of salt, a liberal sprinkling of black pepper, with a drop or two of tabasco sauce; stir thoroughly until the salt is dissolved and then add five tablespoonfuls of olive oil.

taste, like the midrib of a lettuce leaf, with a slight but most agreeable suggestion of pine flavor. The tenderest young shoots of celery could not be more brittle than these blanched stems of udo.

From the 1st of October until the middle of May this vegetable is for sale in the markets of Japan, and in this winter character, aside from its being an excellent salad, lies its great value. It is comparatively cheap and is eaten by the poor Japanese as well as by the rich.

From its adaptability to winter culture and its excellent quality, this plant deserves to become as well known as asparagus or celery.

Botanically the plant is known as *Aralia cordata* Thunb. It has been recognized as an ornamental plant in Europe and America, where its large, sharply lobed, regular leaves have been highly prized for their decorative effects. (See Pl. IV.) The edible portions of the plant are its young shoots, which are blanched by being covered with earth.

There are two varieties of udo, called respectively "kan udo" and "moyashi udo," and these, though of similar appearance as they are placed on the market, are quite differently cultivated.

Through the assistance of Mr. H. Suzuki, of the Yokohama Nursery Company, I was able to learn from the growers of this vegetable how it should be cultivated. Its cultivation is not difficult and will be easily understood by anyone acquainted with the ordinary methods of forcing asparagus.

THE CULTIVATION OF KAN UDO.

The seeds of this variety are sown broadcast in seed beds, prepared of rich garden earth, in the month of March or April, and are allowed to grow there for one year. The following spring the individual seedlings are transplanted from this seed bed, after the tops, which have died during the winter, have been removed, and they are then set in rows 2 feet apart and 10 inches from each other in the rows. In these rows they are cultivated all summer, or until September, when the leaves begin to turn brown. The stems are then cut back close to the rootstocks and the earth is piled up in a mound 2 feet high above the latter. In forty days the new shoots, which begin to form as soon as the old ones have been cut back, appear above the surface of the mound. They are then ready for cutting, and the mound is opened and the marketable shoots cut. Each rootstock produces about five of these blanched shoots, three of which are probably fit for the market at the first cutting, early in October. The remaining small shoots are covered up again and allowed to grow for a second cutting a week or so later. In removing these shoots for market care is taken to cut close to their bases, so as not to leave stubs, as the presence of the latter is said to prevent the rapid growth of the remaining young shoots.

Generally only two crops of shoots are secured of the kan udo, but occasionally there are three. After the removal of the last crop the rootstocks are buried and allowed to remain over winter. In the spring the mounds are opened and rich manure is applied in trenches running on both sides of the plants. Throughout the summer the plants are allowed to grow and are again cut down in autumn and treated in a similar way to that just described. The life of the kan udo rootstock is more than ten years, but beyond that age its use ceases to be profitable.

Although generally grown from seed, this variety can be reproduced from root cuttings, though the latter method is considered less practicable, owing to the fact that the large root cuttings take up more space in the field.

The season for kan udo is October and November, and being the earliest variety and occupying the fields to the exclusion of other crops it is also the dearest, sometimes selling for as much as 25 cents for a bundle of 16 shoots. It is not otherwise preferable in any way to the other variety, which first appears in the market toward the end of November.

THE CULTIVATION OF MOYASHI UDO.

The moyashi or forcing udo is grown from root cuttings, which are purchased by the growers from special cultivators who have their seed beds on the slopes of Fujiyama. These young sets, which have been grown from seed the year before, are dug in November and kept all winter packed in straw. They are bought in early spring by the cultivators and kept ready for planting, which is done during March and April.

The root cuttings are laid lengthwise in a shallow trench about 4 inches apart, and in the space between them a small quantity of rich manure is placed. They are then covered with 2 inches of soil. As the leaves appear, the trench is gradually filled about their bases, and, with the usual cultivation to keep down the weeds, the plants are allowed to grow until the end of October, or until frost. These two-year-old plants are then dug, the dead stems are removed, and the plants packed away in a dry place until wanted for the forcing bed. They may be kept for several months in this dry condition without injury.

The forcing bed is made by digging a trench 3 feet wide and 2 feet deep and putting on the bottom a thin layer of barley husks or a sprinkling of bone dust, over which is spread an inch of rich, light garden soil, mixed with about 10 per cent of leaf mold.

The dry udo sets, which are kept in stock, are packed as closely together as they can stand in the bottom of the trench, which is filled in and heaped up with the same light soil. In about fifty days the first shoots appear above the mound and are cut, like asparagus, by digging down to the base or by inserting a long knife into the mound.

By preparing a series of forcing trenches and planting them at different times, fresh shoots of the moyashi udo can be had all winter long, from November until the beginning of May.

At the close of the forcing season the rootstocks are taken from the trench, planted out in rows, manured heavily, allowed to grow all summer, and forced again the following winter. These same roots are used for several years. (See Pl. V, figs. 1, 2, and 3.)

Although cheaper than the kan udo, this forcing variety will probably be better suited to our American conditions, for it yields shoots throughout the winter, while the other sort produces them only in October and November. The mild winters in Japan make these forcing beds in the open ground possible, and it is probable that as far north as Norfolk, Va., the culture of udo in a similar way could be carried on; if not, certainly Florida and California truck growers could cultivate the plant. The kan udo might be grown even farther north where the ground does not freeze until after the last of November.

WASABI, THE HORSE-RADISH OF THE JAPANESE.

INTRODUCTION.

There is a fresh sharpness about Japanese wasabi that not even the finest Austrian sorts of horse-radish possess. The color, too, is not generally white, but a delicate shade of green, and although served much in the same way that horse-radish is served in America, it is quite a different thing.

The roots, which are grated up to prepare this Japanese appetizer, are produced by a plant of the same family as the true horse-radish and the mustard, and botanists give it the name of *Eutrema wasabi*. (Pl. VI., figs. 1 and 2.)

To anyone fond of such things this Japanese horse-radish will prove an acceptable novelty, and it is with the object of acclimatizing wasabi in America that a few young plants have been secured and will be propagated and tested in the trial gardens of the Department of Agriculture.

In Japan grated wasabi is a constant accompaniment to the raw fish which forms such a prominent part of a Japanese meal. Without it the fish would taste as unnatural to a diner as blue-point oysters on the half-shell without horse-radish would taste to the average American. Wasabi is, in fact, universally used in the inns and tea houses of the country.

The wasabi plant is a peculiar one to cultivate, and there are certain localities in Japan where it is grown, notably in the region about Hiroshima. It is popularly believed that the culture must be carried on in running water, but this is not absolutely correct, for near Nara, in the little village of Kiriyama, there are patches of wasabi which have been grown for many generations by the same family in a location not flooded with water.

With Mr. K. Yendo of the Tokyo Botanic Gardens as interpreter, the writer visited, in June, 1902, one of the cultivators of wasabi and gleaned from him a number of facts about the culture of the vegetable. Mr. Kawakita, whose father and grandfather before him had grown wasabi, carried on its cultivation—as the growers of Fourche Maline do the horse-radish—only as a secondary crop. His patches of the plant were in a narrow valley, shaded by persimmon trees, where the soil was wet by underground springs, just such a place as one would expect to find ferns in were the ground not cultivated. (See Pl. VI, fig. 2.)

Owing to the ravages of a small caterpillar which had riddled the leaves with holes, the plants presented a sorry enough appearance, and the owner took no pride in showing them. The general appearance of the slopes of the little valley was as if they had been covered with a coarse, broad-leaved dock like the *Petasites*, which is common in parks in Europe.

THE CULTIVATION OF WASABI.

The method of culture practiced by Mr. Kawakita is a simple one enough, the chief point being the selection of a suitable location for the patch. Moisture is essential, and the borders of a mountain brook or a bit of "springy" meadow in the hills would form a suitable situation. Shade is likewise looked upon by this gardener as necessary, and that cast by the kaki or Japanese persimmon trees is preferred. The soil is a stiff clay, mixed with gravel, which retains moisture for a long time.

In the month of June, when the 2-year-old plants which are ready for market are dug, the young suckers are carefully removed from the marketable roots and are planted out in the field. They are set in rows that are 1½ feet apart and are put only 10 inches from each other in the rows. Weeding is done as found necessary, and in February or March the plants are hilled up to make them produce longer and larger roots for the market.

Liquid manure and rape-seed cake are two of the principal fertilizers of the country, and these are applied judiciously in November and March in quantities varying according to the soil conditions.

For two years the young wasabi plants are cared for in the field, at the end of which time their roots are large enough to be dug. Over 2 tons of these roots are said to be harvested from an acre.

The roots are prepared for market by washing off the dirt, cutting back the tops, and binding into bundles. They keep for some time, just as horse-radish does. There is said to be a difference between the wasabi which is grown directly in the running water and that cultivated in wet locations in the mountains, the former having a greener color. Roots that are grown in the mountains have a finer flavor than those which are cultivated on the plains, it is said.

The roots are generally grated and served as horse-radish is served in America, but they are sometimes pickled with sake vinegar, the residue from the rice wine of the country, or are used to give a snap to certain kinds of confectionery. The fresh leaves are also employed in the manufacture of a pepper sauce by putting them in a bottle, pouring hot water over them, and allowing them to stand for several hours.

A vegetable which has become to the Japanese what horse-radish is to the Occidentals can hardly fail to attract the attention of those Americans who are seeking new and appetizing relishes.

PLATES.

DESCRIPTION OF PLATES.

PLATE I. *Frontispiece.* A hillside covered with mitsumata paper plants, near Shizuoka, Japan.

PLATE II. Fig. 1.—Mitsumata plant two years after transplanting from nursery row. Fig. 2.—Three-year-old shoots rising from an old mitsumata stump, near Shizuoka.

PLATE III. Fig. 1.—A bundle of stems of mitsumata after the paper-producing bark has been removed. Fig. 2.—Boards covered with drying sheets of mitsumata paper.

PLATE IV. Plants of the kan or summer udo growing in the field. From a photograph taken on the experiment station grounds of Marquis Matsudaira at Fukui, Japan, by Yendo.

PLATE V. Fig. 1.—Young root cutting of the forcing udo after it has been planted for a week or two in the spring, showing the way the new shoot springs from the horizontally laid cutting. Farsari, photographer, Yokohama. Fig. 2.—Old root of the forcing udo after it has been long enough in the soil in spring to start well into growth. Farsari, photographer, Yokohama. Fig. 3.—Blanched young shoot of forcing udo, more than 2 feet in length, as taken from the forcing bed in May. The white portion only is edible, the dark part being the old root, which produces, one after the other, several such edible shoots. Farsari, photographer, Yokohama.

PLATE VI. Fig. 1.—Young wasabi plants ready to set out. The marketable roots look much like these. Fig. 2.—A patch of wasabi growing on a shady hillside.

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FIG. 1.—MITSUMATA PLANT TWO YEARS AFTER TRANSPLANTING FROM NURSERY ROW.

FIG. 2.—THREE-YEAR-OLD SHOOTS FROM AN OLD MITSUMATA STUMP.

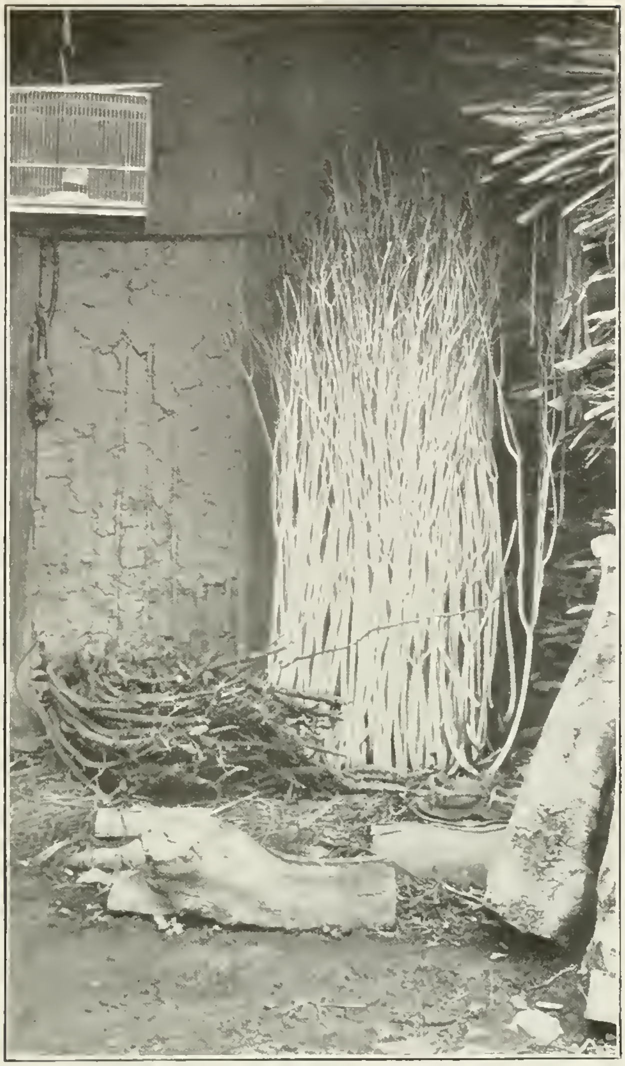

FIG. 1.—A BUNDLE OF PEELED STEMS OF MITSUMATA.

FIG. 2.—BOARDS COVERED WITH DRYING SHEETS OF MITSUMATA PAPER.

THE UDO PLANT IN THE FIELD.

FIG. 1.—YOUNG ROOT CUTTING OF UDO PLANTED IN THE SPRING, SHOWING NEW SHOOT.

FIG. 2.—OLD ROOT OF UDO PLANTED IN THE SPRING, ON WHICH A YOUNG SHOOT HAS FORMED.

FIG. 3.—BLANCHED YOUNG SHOOT OF UDO MORE THAN TWO FEET LONG. TAKEN FROM THE FORCING BED IN MAY.

FIG. 1.—YOUNG WASABI PLANTS READY TO SET OUT.

FIG. 2.—A PATCH OF WASABI ON A SHADY HILLSIDE.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN No. 43.

B. T. GALLOWAY, Chief of Bureau.

JAPANESE BAMBOOS

AND THEIR INTRODUCTION INTO AMERICA.

BY

DAVID G. FAIRCHILD, Agricultural Explorer.

SEED AND PLANT INTRODUCTION AND DISTRIBUTION.

Issued July 3, 1903.

WASHINGTON:
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1903.

BULLETINS OF THE BUREAU OF PLANT INDUSTRY.

The Bureau of Plant Industry, which was organized July 1, 1901, includes Vegetable Pathological and Physiological Investigations, Botanical Investigations and Experiments, Grass and Forage Plant Investigations, Pomological Investigations, and Experimental Gardens and Grounds, all of which were formerly separate Divisions, and also Seed and Plant Introduction and Distribution, the Arlington Experimental Farm, Tea Culture Investigations, and Domestic Sugar Investigations.

Beginning with the date of organization of the Bureau, the several series of bulletins of the various Divisions were discontinued, and all are now published as one series of the Bureau. A list of the bulletins issued in the present series follows.

Attention is directed to the fact that "the serial, scientific, and technical publications of the United States Department of Agriculture are not for general distribution. All copies not required for official use are by law turned over to the Superintendent of Documents, who is empowered to sell them at cost." All applications for such publications should, therefore, be made to The Superintendent of Documents, Union Building, Washington, D. C.

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21. List of American Varieties of Vegetables for the Years 1901 and 1902. 1903. Price, 35 cents.

[Continued on p. 3 of cover.]

BUREAU OF PLANT INDUSTRY.

BEVERLY T. GALLOWAY, *Chief of Bureau.*

SEED AND PLANT INTRODUCTION AND DISTRIBUTION.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., May 16, 1903.

Sir: I have the honor to transmit herewith a paper entitled "Japanese Bamboos and Their Introduction into America," and respectfully recommend that it be published as Bulletin No. 43 of the series of this Bureau.

This paper was prepared by Mr. David G. Fairchild, Agricultural Explorer, who has been detailed by you to accompany Mr. Barbour Lathrop on his expeditions in search of valuable seeds and plants, and it has been submitted by the Botanist in Charge of Seed and Plant Introduction and Distribution with a view to publication.

The illustrations which accompany this paper, consisting of eight half-tone plates, are considered essential to a full understanding of the text.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

The bamboo has long been known as one of the best of ornamentals wherever the climate is sufficiently mild to permit of its cultivation, but besides its value as an ornamental the bamboo has in its native home a multitude of uses which make it one of the most important plants in the economy of Japanese life.

Both Mr. Barbour Lathrop and Mr. Fairchild are convinced that the bamboo may be adapted to many uses in America, and the present bulletin is intended to call attention to the possibilities in this direction and to describe some of the most important species.

A. J. PIETERS,
Botanist in Charge.

OFFICE OF BOTANIST IN CHARGE OF
SEED AND PLANT INTRODUCTION AND DISTRIBUTION.
Washington, D. C., May 8, 1903.

CONTENTS.

ILLUSTRATIONS.

JAPANESE BAMBOOS AND THEIR INTRODUCTION INTO AMERICA.

INTRODUCTION.

This bulletin represents a small part of the work accomplished by Mr. Barbour Lathrop's third expedition in search of valuable seeds and plants, and comprises material gathered during a four months' stay in Japan.

Its object is to call the attention of American cultivators to a group of the most beautiful and useful of all plants which has hitherto been neglected by them, either because they believe it adapted only to a tropical climate or to be of only ornamental value, and to point out how far both of these views are fallacious.

Anyone who has attempted to collect data in an Oriental country will appreciate the difficulties which are encountered in working through an interpreter, and will understand that some of the statements in this bulletin must depend upon the accuracy of the translations. Mr. K. Yendo, of the botanic gardens in Tokyo, was, however, particularly well fitted to interpret on botanical matters, and it is hoped few errors have been made.

The writer wishes to express his indebtedness and gratitude for assistance to Mr. T. Makino, of the Tokyo Botanic Gardens, who is the Japanese authority on bamboos; Mr. Isuke Tsuboi, of Kusafuka, near Ogaki, who is one of the best amateur cultivators of these plants; and especially to Mr. H. Suzuki, of Yokohama, for most valuable advice and assistance regarding transplanting and shipping.

The valuable work of Sir Ernest Satow on "The Cultivation of Bamboos in Japan," in Volume XXVII of the Transactions of the Asiatic Society of Japan (1899), and above all, "The Bamboo Garden," by Mr. Freeman Mitford (1896), which is the most attractive and useful book ever written on this group of plants, have been drawn upon largely, especially in the preparation of the descriptions of the various species.

GENERAL CONSIDERATIONS.

The bamboo groves of Japan are not only one of the most striking features of its landscapes but one of its most profitable plant cultures.

The largest well-kept groves in the world, except perhaps those of Burma, are growing in the central provinces, and some of these are several square miles in area. In the Tropics generally the bamboo is cultivated in small clumps, but in Japan it is grown with almost the same care that is given to the field crops.

No other nation has found so many artistic uses for the plant as the Japanese, and in no other country, except it be China, is such a variety of forms employed by the common people.

The plant is a necessity to the Japanese peasant; it forms one of the favorite themes of the Japanese artist, and out of it are manufactured some of the most delicate works of Japanese art. The bamboo is in fact one of the greatest cultivated plants of this plant-loving race.

It is a popular misconception that bamboos grow only in the Tropics. Japan is a land of bamboos, and yet where these plants grow it is not so warm in winter as it is in California. In regions where the snows are so heavy that they often break down the young stems and where the thermometer drops to 15° (F.) below the freezing point, the largest of the Japanese species grows and forms large groves.

For many years the gardens of France and England have been beautified by clumps of these Japanese bamboos, and even in America occasional plants can be found growing in the open air, which prove the possibility of acclimatizing these representatives of this most useful family of plants. A temperature of 6° F. has not proved fatal to a large number of the hardy kinds in England.

Although nearly every description of those regions where bamboos grow gives some account of their uses, there is still in the minds of many Americans a doubt as to the value of these plants for growth in the United States.

Bamboos are not like new grains or fodders which will yield prompt returns in money, but they are essentially wood-producing plants, whose timber is unlike that of any temperate-zone forest trees, and is suitable for the manufacture of a multitude of articles for which our own woods are not well adapted. They are the most convenient plants in the world for cultivation about a farmhouse, and in those regions where they can grow would, if introduced, prove themselves in time one of the greatest additions imaginable to the plants of the common people.

The Japanese and Chinese, who are the most practical agriculturists in the world, have for centuries depended upon the bamboo as one of their most useful cultures, and the natives of tropical India and the Malay Archipelago would be much more at a loss without it than the

American farmer without the white pine, for they are not only dependent upon it for their building material, but make their ropes, mats, kitchen utensils, and innumerable other articles out of it, and at the same time consider it among the most nutritious of their vegetables. To enumerate the uses of such a family of plants as this would be like giving a list of the articles made from American pine, and it would not serve the purpose of this bulletin so well as to simply point out the fact that the wood of this bamboo is suited to the manufacture of a different class of articles and fills a different want from that of any of our American woods. Every country schoolboy is aware of the superiority of a bamboo fishing pole over any other. Its flexibility, lightness, and strength distinguish it sharply from any American poles, and make it better suited for a fishing rod than one made from any wood grown in this country. It is because the American schoolboys are so firmly convinced that the bamboo fishing poles are the best that the importers are warranted in shipping into the United States from Japan every year several millions of them.[a]

The thin, flexible ribs of the imported Japanese fan are made from the wood of the same plant, and no one can fail to recognize the peculiar fitness of the material for this particular use.

These are two uses of bamboo wood which illustrate its character, and must be familiar to nearly everyone. When one realizes, however, that they are selected from over a hundred, which would be just as familiar to the Chinese or Japanese, it seems highly probable that this wood must be applicable to many other needs among Americans, which a closer acquaintance with it would reveal. Santos Dumont has employed bamboo extensively in the framework of his dirigible balloons, and Edison once used it in his incandescent lamps.

Americans see in America only the imported poles or manufactured articles as a rule, and from these it is very difficult to imagine the multitude of uses to which the green, uncured stems are put. It is for just such things as can be made quickly from the green shoots that the plant is peculiarly fitted, and this suitability for making all sorts of handy contrivances is one of the principal reasons why it should be made a common plant among the farmers of those parts of our country where it will grow.

The bamboos belong to the family of the grasses, and if this fact is kept in mind many peculiarities of their habits and characters will be easily understood. They should be distinguished, however, from the reeds, of which we have a number in America, especially such as are called "bamboo reed" or "Arundo" (*Arundo donax*), a rank-growing grass, with stems bearing long broad leaves to their very bases.

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[a] The writer was informed by a large grower near Kyoto that 10,000,000 are exported from Japan every year, and that the largest share of them goes to America.

These reeds, although useful, have very soft stems, which are entirely different in texture from those of the true bamboo. The canebrakes of the South are made up of a species of bamboo, but unfortunately the wood of this species is of very little value. The tall, plume-like stem of the bamboo, which sometimes reaches a height of 100 feet, has many of the characteristics of a giant grass (Pl. I). It is composed of joints, is hollow (Pl. VIII, fig. 1), and grows to its full height from a creeping underground stem in a few days, quite as does a shoot of quack grass. The rapidity with which a new culm grows is one of the most remarkable facts about it, and often bewilders the layman, who is accustomed to judge the age of a tree by its size (Pl. VII). Over a foot a day is not an unusual rate during the most rapid growth—a rate of 3 feet per day has been recorded—and a shoot more than 20 feet high may be less than fifty days above the ground. Its development may be compared in a rough way to that of a shoot of asparagus, and anyone who has seen how easily a young stem of bamboo can be snapped off by merely shaking it will appreciate this comparison.

In common with the stems of grasses, those of the bamboo have a hard, siliceous exterior, which makes them more impervious to moisture and more durable than ordinary wood of the same weight. The presence of partitions at short intervals, which cut up the hollow stem into natural receptacles, is another valuable characteristic. These partitions can, however, be easily removed, and the hollow stem used as a pipe, or the pipe can be split open from end to end to form two semicylindrical troughs. The ease with which the green stems can be split into slender pieces, which range in size from half that of the stem itself to the fineness of a horsehair, is one of the most remarkable qualities of the wood, and makes it adapted to innumerable kinds of basket, sieve, screen, and mat making. The fact that no long process of curing is necessary before stems which have been cut fresh from the forest can be used is one of the qualities that makes the plant of such great convenience in the peasant homes of the Orient. Many of the articles of bamboo manufacture could be replaced by metal ones, but it is the convenience of having always at hand a stock of material which can be easily made into a host of improvised things that makes the plant so valuable. This latter is a point which should appeal especially to Americans, who are called the handiest people in the world.

The employment of the young sprouts as a vegetable is alone worthy of the serious attention of our cultivators, for the fondness which many American residents show for bamboo shoots indicates the possibility of creating a demand for them in America.

But in addition to the uses of the bamboos as timber and food plants their value from an æsthetic standpoint is incontestable. They are among the most graceful forms of vegetable life that exist, and add an indescribable charm to any landscape (Pl. I). No one who has ever seen them in China or Japan can fail to have been impressed with their beauty or convinced of the great charm which they lend to the otherwise often monotonous character of the scenery. They are waving plumes of delicate green foliage, which, whether seen against the sky line or backed by a darker mass of forest, always give a peculiar softness to the scene.

Nearly every farmhouse has growing near it a clump of some one of the useful species, and the graceful mass of culms transforms what would be an uninteresting plaster and tile house into a pretty, picturesque home.

It is, however, the introduction of the hardy representatives of this remarkable family of plants into the United States that should attract the attention of Americans, and the object of this bulletin is to show how the various kinds of bamboo are cultivated in Japan, and to suggest how these methods of cultivation can be applied to American conditions.

As might be expected, in a group of plants containing hundreds of species, there is a great range of hardiness among them. Some of the Japanese forms are able to thrive in the coldest regions of Hokkaido, the North Island, while others are too tender to be grown successfully even in the comparatively mild climate of the central provinces.

There is also a great range in the size of the different species. Some are so small that they creep over the ground, forming a reed-like, rank-growing greensward (Pl. VII, fig. 2), while others grow to a height of 40 feet or more and produce stems which are 6 and 7 inches in diameter (Pl. IV). Certain forms are suited only for potting purposes and are chosen by the Japanese gardeners as objects upon which to practice their dwarfing art (Pl. VII, fig. 1), while others are grown in forests which are many acres in extent.

While the introduction into America of some of the smaller forms is a desirable matter, the main interest attaches to securing and establishing the hardy forest species.

As previously remarked, there are many plants of Japanese bamboos already growing in America. Clumps of the very hardy kinds may be seen occasionally in private gardens or public parks in the South, even as far north as Washington; but owing either to the difficulty of getting the plants or a failure to understand their management these have never become popular farm plants. Potted specimens of the small species are to be met with in many florists' collections, and some are used as lawn plants, but the employment of even these is very limited.

In California, where the Japanese and Chinese species thrive very well, there are many large specimens, and even one small forest, while a number of Californians are enthusiastic bamboo fanciers. Dr. H. Tevis, of San Francisco, has probably the largest collection on the

Pacific coast, and his brother has a grove at Bakersfield in which stems over 40 feet high are said to be growing. The Golden Gate Park has several clumps which are very promising, and Mr. McLaren, the superintendent, was most enthusiastic over an offer by Mr. Lathrop to present several thousand to the park, with which to start a grove or two of more than a half acre in extent. In the grounds of a nursery company at Niles, Cal., there are several rows (Pl. VIII) of the timber bamboo, individuals of which are certainly 25 feet in height; and a beautiful little grove, probably of *Phyllostachys quilioi*, in the town of Berkeley, was destroyed a few years ago to make way for a street. In Florida the well-known nursery firms have already imported many different species.

Mr. Lathrop is assisting the Department of Agriculture in an attempt to introduce on a large scale the best of the Japanese timber sorts and arouse the interest of a large class of cultivators in those regions where the plants are likely to succeed, and it is to be hoped that the time is not far off when many thousands of young plants will be set out through these sections of the United States.

GENERAL CHARACTERS OF THE JAPANESE BAMBOOS.

Bamboos are not trees, although their stems or culms are sometimes as large as tree trunks, and it is essential that their character as grasses be kept in mind.

They have the power of producing seeds, which resemble (in Japanese species, at least) kernels of rice or barley, but they flower as a rule only at intervals of many years, and very few of the flowers ever form seed. The formation of mature seed is so uncommon in Japan that Mr. Makino, of the Tokyo Botanic Gardens, who is writing a monograph on the family, says he has never seen the seed of certain of the common species.

In the almost total absence of the method of reproduction by seed the bamboos have developed their rhizomes, or underground stems, and it is upon these that the spread and multiplication of the individuals depends. Unlike an ordinary tree, therefore, a clump of bamboos has underground stems in addition to its root system. A mass of these creeping rhizomes, which grow out in various directions from the base of the clump, give rise every year to the new shoots which increase the diameter of the clump. A single rhizome, according to Dr. Shiga, chief of the bureau of forest management in Tokyo, continues growing for four seasons and then ceases, but from the bases of the shoots it produces new rhizomes grow out which have a similar period of growth. If these underground stems or rhizomes are injured or checked in any way from spreading freely through the soil, the clump of aërial shoots will remain small; but if given rich soil and abundance of moisture a few plants will spread gradually until they cover a considerable area.

The new shoots of bamboo are produced by different species at different seasons of the year. The majority of Japanese species send up their new stems in the spring, beginning in April and May, and it is these sorts that stand the best chance of succeeding in America, because our cold winters will kill back any young growth produced late in the summer.

This growing period is the most critical one in the life of the plant, as the shoots during development are easily injured by winds, frosts, or droughts, and it is upon the growth of these young stems that the beauty of the clump during the summer depends.

If one examine a rhizome of bamboo (Pl. VI, fig. 3) it will be seen to have at short intervals partitions or nodes, above each of which is situated a small pointed bud, and from each bud arises a number of fibrous roots. It is by the elongation and thickening of these buds that the new shoots are formed, and if it is injured, though the rhizome may remain alive for many years, it will not produce any new buds or shoots from these nodes.

When a bud at the node of one of the underground stems has swollen until it is much larger in diameter than the rhizome which supports it and has sent down a number of good, strong roots, it begins to elongate and push its way up through the soil. Tough, overlapping sheaths protect the tender tip from injury, as well as the undeveloped branches on the sides of the elongating shoot. These sheaths are borne on alternate sides of the stem by each internode or joint (Pl. IV, fig. 1), and are, according to Sir Ernest Satow, characteristic of each species.[a] They are tough and board-like, many of them, often covered outside with fine bristles and characteristically marked; and the tip of each is provided with a leaf-like appendage called *pseudophyll*, which varies in shape with each species. These protecting organs remain closely attached to the stem until it has nearly finished its growth, when they stand out from the stem, allow the young branches hidden beneath to develop, and finally drop off. In some species the sheaths remain attached longer than in others, and in certain species they never drop off, but gradually dry up and break to pieces.

Until the young stem has attained its full height it is quite branchless, like a shoot of asparagus. On reaching maturity, however, the sheaths fall back and the young branches elongate and unfold their leaves. Most large forest bamboos have no branches near the ground, the first four or six nodes failing to produce them. When grown in

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[a] The Cultivation of Bamboos in Japan. Trans. Asiat. Soc. Japan, Vol. XXVII, Part III, 1899. Price, 5 yen.

dense masses even the first twenty or more are often devoid of branches. The smaller the shoot the more likely it is to branch from the lower nodes.

The leaves of bamboo vary greatly in size, but have one general lanceolate form, some being nearly a foot long by 6 inches wide, and suitable for wrapping material; but the majority of forest forms at least have leaves from 2 to 6 inches long. Mr. Mitford points out in his most interesting book, "The Bamboo Garden," that the leaves of all hardy species in England have not only the parallel longitudinal nerves which are common to all bamboos, but delicate cross nerves which give a leaf the appearance, when held up to the light, of being covered with a network of veins. All species tested by him which did not have these "tesselated" leaves, as he calls those leaves with cross as well as longitudinal veins, proved tender in England.

Little use is made of the foliage of most species of bamboo, a few only being used for fodder where better food in not obtainable. One species in Hokkaido is said to be browsed over by the few cattle which are there. When first produced the young foliage is often of a dark-green color, but as it becomes older it changes to a lighter shade of green, and on very old culms it often has a yellowish tinge. These differences in the color of the foliage are what give such a variable appearance to a bamboo forest.

Although produced in a few weeks, a stem requires three or four years to harden and become fit for use, and if left standing in the forest too long, or until it becomes yellow, it loses much of its elasticity. Culms that are twenty years old have lost much of their beauty, the foliage becoming scant and the stems yellow and scarred.

The roots of the bamboo resemble those of Indian corn. They are brittle and easily broken and are never of any great size, but are formed in large masses from the nodes of the underground stems.

PROPAGATION OF JAPANESE BAMBOOS.

If Japanese bamboos produced seed, the cheapest and safest way to propagate them would be by importing large quantities of the latter and growing them in seed beds; but as none of the useful species bears fruit, except at very long intervals, it is necessary to propagate the plants by other means. Two methods have been practiced, one of which, however, is only used to a limited extent.

The safest way is the simple one of digging up young plants, separating them from the mother clumps, and transplanting them to the desired situation. This method seems very simple, but there are several essential points regarding it which must be attended to if the transplanting is to prove a success. If the transplanting is only from a forest to a location near by, it may be done at any time during the growing season. In Japan this period extends from April until July, inclusive. If, however, the plants are desired for planting in a foreign country, America, for example, they should be dug early in April, set out in nursery rows, and allowed to grow until the middle of July. Those which in July show a new growth from the rhizome should then be transplanted again into the same kind of soil, and in October they will be in condition for digging and shipment. Mr. Tsuboi, of Kusafuka, cuts back the culms on his young plants to one or two nodes when he first digs them in April, at which time they form a rosette of leaves near the ground (Pl. VI, fig. 1). When treated in this way they produce small plants which would be very economical for shipping, as they require little box space.

Much depends upon the selection of the young plants whether or not a vigorous clump results from its planting in a few years. The mother plant should be inspected to see if it is in good health. If the branches are affected by what is known as "witches' broom," which makes gnarled, irregular tangles of the small branches, young plants should not be taken from them. A species of smut (Ustilago) sometimes affects the young branches and produces an appearance similar to that of the witches' broom, but this is less abundant than the former disease. The larva of a species of beetle, whose habits are not yet fully known so far as could be ascertained, sometimes causes considerable damage by boring into the young shoots and penetrating through segment after segment of the young growth, stunting the culm and completely ruining it for timber purposes (Pl. VII, figs. 3 and 4). A young plant in bloom is considered worthless for transplanting, as it seldom gives rise to new shoots.

The proper way is to select a young plant with branches near the ground and cut down with a spade or other cutting tool on all sides of the base at a distance of not less than 8 inches, severing the rhizomes which connect the plant with the mother clump. Dig out a good-sized ball of earth with the roots inclosed in it, shake off the superfluous earth, cut back the stem to two branch-bearing nodes, and transfer to a nursery row (Pl. VI, fig. 2). If no rhizome is dug up with the plant, or if the rhizome is dead, the plant may live on for several years, a rosette of leaves forming at the top of the stem, without the formation of any new shoots (Pl. VI, fig. 2). Mr. Tsuboi is of the opinion that plants with dead rhizomes will live for seven or eight years and appear perfectly healthy. The plant is kept alive by the fibrous roots, but has no power to form a new rhizome. In the purchasing of plants from nursery companies the principal point to ascertain is whether the rhizome is alive and in vigorous condition. The part above ground may be to all appearances in good health, while the rhizome is dead, making the plant worthless.

If these properly dug plants which have been set in nursery rows in April are inspected in July some of them will have begun the formation of new shoots from their active rhizomes. Plants of which the rhizomes show no signs of activity, it should be emphasized, are probably weak and should not be chosen for the second transplanting, especially if designed for a long ocean voyage. In October the twice-transplanted bamboos, hardened by this transplanting process, are dug and their roots, together with a ball of earth, are wrapped with coarse straw twine, surrounded with a layer of moist sphagnum, and packed carefully in well-aired boxes. All holes in such boxes should be carefully closed with wire netting to keep out rats during the voyage. Very little foliage should be left on the plants when they are shipped in this way (see Pl. VI, fig. 2). October is the best month for shipping from Japan, because the plants have by that time gone into a dormant condition and travel safer, and the extreme cold weather will not have begun before they reach their destination in America.

Even with these precautions, the plants on arrival after a sea voyage require special attention. According to Mitford, who has had much experience with their importation, they should not be planted out in their permanent places before they have recovered from the effects of the journey. The balls of earth should be first thoroughly soaked in water and the plants then potted and placed in a cool house for the winter. The leaves, or bare culms, if the leaves are lost, should be copiously syringed twice a day, but the roots should not be kept too moist. Early in May the plants should be hardened off as one hardens off geraniums for bedding out, and at the end of May or beginning of June they will be ready to plant in their permanent places.

This should be in soil which has been especially prepared the previous autumn by double digging to a depth of 18 inches. In setting out, great care should be taken not to trample down the soil too roughly about the roots, as there is great danger of injuring the brittle buds on the rhizomes or the tender fibrous roots. It is best, Mr. Mitford says, to consolidate the plants by watering freely. After planting, the ground should be thickly covered with a mulch of dried leaves (Pl. II), under which is a layer of cow manure; and this mulch should be kept on during the summer months to allow the plants to form a good strong system of underground stems and fibrous roots.

The above method, which embodies the experience of such students of the bamboo as Mr. Mitford, Mr. Tsuboi, and Mr. H. Suzuki, is probably the safest one and in the end most economical.

It has been found unnecessary by such cultivators as Mr. J. McLaren and Mr. John Rock, of California, to pot the plants on arrival in such a warm climate as California. They are merely heeled in, given plenty of water, and set out the following spring.

The other method of propagation is to dig up, in the winter, lengths of 1-year-old rhizome 3 feet or so long, rub the cut ends with wet ashes, allow these wet ashes to dry, and pack carefully in a tight box in fine, almost dry soil (Pl. VI, fig. 3). Upon arrival these rhizomes are set out in properly prepared ground. The shipment should be timed to arrive at its destination in the early spring, so that the cuttings can be set out at once. This method is recommended by Mr. Mitford for the commercial nursery propagation of the bamboo, but he does not advise its employment if the plants are to be shipped long distances, and the author has failed to find that it has been successfully tried. Mr. John Rock, of Niles, Cal., thinks bamboos could be propagated quickly in this way.

Even with the best of care in transplanting by the first described method the Japanese bamboo growers count on losing at least 10 per cent of their young plants, and if the conditions are not altogether favorable, as high as 20 per cent of failures may be expected.

SUITABLE LOCATION AND SOIL CONDITIONS FOR BAMBOOS.

In Japan some of the best groves are surrounded by paddy fields, and the soil is a rich, stiff loam, lightened with a mixture of sand. Those visited by the writer are on the open plain and stretch up and down a small brook for 5 miles or more. Whatever winds blow over this small plain must strike the forests, but it is safe to say that such winds are not strong ones. A favorite site for a bamboo grove is the base of some range of hills or a broad valley where some mountain stream has brought down and deposited a mass of alluvium. These situations have the double advantage of suitable soil and shelter from strong winds. This latter point is said by every grower to be an important one, for the young shoot, as soon as it is tall enough to come in contact with the branches of the older ones, is thrashed about by the winds and its growing tip is injured. This injury stops its growth at once and the resulting culm is imperfect. Wind-breaks of conifers are sometimes planted to protect a grove which is in an exposed position. In America, where the prevailing winds are probably as a rule stronger than they are in Japan, special attention will have to be given to this matter of wind-breaks.

The quality of the soil on which a bamboo stem is grown influences materially the texture of its wood. So fully is this realized by the Japanese that there is one particular mountain side which has the reputation of producing the hardest, flintiest bamboo in the country. The culms grown at Togeppo are cut up and made into the cylindrical ash boxes, or "haifuki," upon the edge of which the smokers strike their metal-trimmed pipes in order to knock out the ashes. After years of use the edge of the Togeppo ash box remains smooth, while that made from a stem grown in the lowlands is splintered to pieces.

Potash and phosphoric acid are very important elements in the formation of a strong, tough wood, and although their use in fertilizers does not make so much difference in the rapid growth of the culm as that of nitrogen they are quite as important.

A well-drained soil is just as necessary for bamboos as for many trees, for although these plants require much moisture they are not swamp plants, like canes or reeds. Land which is occasionally overflowed can be planted to advantage with bamboos, according to Mr. Tsuboi, if they are set on low mounds or ridges; but stagnant pools of water will kill the rhizomes if allowed to stand over them for many weeks. Embankments of canals, the borders of ponds, and river banks are suitable situations, especially in dry regions. Large clumps are growing along the canals in Egypt, and Algiers has many varieties growing in her trial gardens which are watered only by irrigation. There are in California, Oregon, Texas, and throughout the Gulf and Southern States thousands of suitable locations. The banks of small streams, the deltas of rivers, low, irrigated islands, like those in the San Joaquin and Sacramento rivers, would produce big forests of these valuable plants, while the banks of irrigation canals, wherever such occur in mild climates, could be made beautiful by them. Any soil which has a large admixture of gravel in it does not prove satisfactory, as the gravel prevents the rapid spreading of the underground stems. Such compact soils as the gumbo soils of the Southwest will probably grow the plants well, but they will presumably not spread as rapidly on such stiff ground as they would upon a lighter loam. If it is the object to produce a large number of big culms, the best soil is one with a fair admixture of vegetable humus. The rhizomes spread rapidly in such humus and produce a fine crop of new shoots. As the roots of the forest species penetrate 3 feet into the soil, the writer is assured that a clay subsoil at this depth is a desirable soil condition. In the cultivation of the edible bamboos (*Phyllostachys mitis*) a lighter, more sandy soil seems to be preferred to that deemed suitable for the timber kinds, *P. quilioi* and *P. henonis*. Most bamboos will not withstand much drought without losing their leaves, but they are not so dependent upon a moist atmosphere as most people imagine. If they are supplied with plenty of water at the roots their leaves will keep green in a fairly dry climate. They must not be considered, however, as drought-resistant plants, but as suitable for irrigated land or regions in which there is at least a moderately regular rainfall. At Niles, Cal., Mr. Rock has bamboos 20 feet high which are watered only twice a year with about 2 inches of water each time (Pl. VIII).

JAPANESE MANAGEMENT OF BAMBOO GROVES.

One of the best posted bamboo growers in Japan informed the writer that twenty years ago he did not know that his groves, which were then in a neglected state, had any money value, but that to-day those parts of his farm on which the groves are situated are its most valuable portions. The attention which he bestows upon them now is very inexpensive, but almost as careful as that given to any other of his crops. The following forest methods are largely those which Mr. Tsuboi described as, from his experience, the best. These are applicable with slight variations to the three principal timber bamboos in Japan, and pertain in a general way to the culture of the ornamental species.

The land chosen for a bamboo grove should be dug over to a depth of 1½ feet the autumn previous to being planted, and, if a heavy soil, should have worked into it a good quantity of trash from the stable. The plants should be set out at an equal distance from each other at the rate of about 300 to an acre, or 12 feet apart each way. If the soil is a dry one, the ball of earth and roots should be planted below the surface of the soil, but if a wet one a mound should be made and the plants set in the upper portion of it. After planting it is important, as already remarked, that the soil between the plants should be given a heavy mulch of straw, under which is a layer of cow manure. This mulch should be maintained during the entire year. In the beginning the roots should be supplied with an abundance of water and in the autumn should be given plenty of rotted manure. If some of the plants die, they should be replaced by others so as to maintain as complete a stand as possible. It is essential as the new shoots spring up that the ground at their bases should be shaded by the foliage. The semiobscurity of a Japanese grove is not only its greatest charm, but one of the necessary factors of its growth. The sooner the ground can be shaded by the plants the better.

For the first three years at least all the shoots that appear should be allowed to mature, but after the grove is once well established only the largest shoots should be permitted to grow, the others being cut out as soon as they appear above the ground. This thinning process throws the strength of the plants into a comparatively few large culms, and gradually increases the height and strength of the forest.

In regions where the snows are so heavy that they break down the plants the practice of bringing the tops of several culms together and fastening them with rope is sometimes followed. The wigwam-like masses formed in this way are able to support without injury the weight of snow.

No culm should be cut for timber purposes until it is at least four years old, as before this time the wood is not mature. On the other hand, if left standing too long the wood becomes too brittle and loses in value, and the forest besides is benefited by the cutting out of the four-year-old stems. The crop of new shoots is larger. This thinning-out process should be so done that as few gaps as possible are made in the forest and the semiobscurity below the mass of foliage is maintained.

The crop of new shoots varies in size every alternate year. A poor crop would mean 6 to 7 per cent of new shoots and a good crop 12 to 14 per cent. As there are commonly 10,000 culms in a hectare[a] (or 4,545 in an acre) of properly planted grove ten to fifteen years old, this would mean the production of 600 to 700 culms per hectare for a light crop and 1,200 to 1,400 for a heavy one. These figures were very kindly furnished the writer by Dr. T. Shiga, chief of the imperial forest management in Tokyo.

The experience of Mr. Tsuboi has been that some kinds of forest trees if standing in a grove prevent the growth of the bamboos near them. Oaks and chestnuts, he declares, are especially objectionable in this respect, while persimmons do not seem to affect in the least the production of new bamboo shoots. The effect of weeds in a forest is undesirable, and although comparatively few species are able to live in such a deep shade these should be dug out as from any cultivated field. Attention to these various details makes a great difference in the amount and quality of timber produced. A grove is not to be looked upon as merely a thicket and left to take care of itself, but as a plant culture which requires attention. Plates II and III show the effects of different methods of treating parts of the same grove.

One important element in the culture of this peculiar timber plant is the fact that a whole forest may bloom and die in a single season, and that it is not possible—as yet—to tell beforehand when this blooming will take place. The intervals between these periods are, however, so long that they are not taken into consideration by the Japanese farmer when he buys a bamboo grove. Little accurate information is obtainable regarding the length of life of the various Japanese species, but *Phyllostachys henonis* has the reputation in Japan of blooming oftener than either *P. quilioi*, *P. mitis*, or *P. nigra*, the other three important timber species. A small grove near Kawasaki which bloomed this season (1902) was reported by the owner to have once bloomed about sixty years before. As there always remain in the field a number of living rhizomes, after the death of the forest, these renew the latter in a few years, so that the actual loss to the owner does not include the cost of replanting. This is the case at least with the Japanese bamboos. As culms which have bloomed are poor in quality, the practice is followed of cutting them as soon as possible after they show signs of blooming.

[a] About 2½ acres.

In Japan, where bamboos and rice are often grown in adjoining plats of ground, some trouble is experienced from the underground stems spreading into the neighboring fields. To prevent this a ditch 2 feet wide and as many feet deep is dug about the grove and kept open by several rediggings during the year. This method is said to be a satisfactory one. It is a difficult matter, however, after a field has once been planted to bamboos, to clear it satisfactorily for other crops, for there is a mass of these tough rhizomes that are very difficult to dig out.

The harvesting of bamboo poles is not done before August, as culms cut earlier than this date are likely to be attacked by insects, not having had time to sufficiently harden. A Kyoto grower of black bamboos remarked that the Kobe exporters, by insisting on having their bamboos for export cut earlier than this date, had seriously injured the foreign demand, as the quality of the wood was much injured by this early harvest.

A saw is often used in cutting the shoots, by making cuts on opposite sides of it near the base. When cut, the poles are classified, tied into bundles, and stacked like hop or bean poles to dry. In the lumber yards of Japan these stacked poles of bamboo form a prominent feature.

PROFITS OF BAMBOO CULTURE IN JAPAN.

Dr. Shiga, chief of the bureau of forest management of Japan, when asked whether bamboo growing was profitable or not, said promptly that it was the best paying plant culture in the country, yielding a net return of 250 yen per hectare, which is the equivalent of about $50 gold per acre. The species referred to by Mr. Shiga in this case was the edible one. Twenty per cent of this amount represents the profits from the sale of edible shoots. Mr. Tsuboi's profits on his groves of *Phyllostachys quilioi*, a strictly timber species, averaged $20 an acre, while those of one of his friends near Kyoto were $40. The profits of a good grove of edible bamboo are evidently greater than those from one grown for timber only, and the author was informed by one of the best bamboo growers near Kyoto that his profits per acre were about $90 on land which, cleared of bamboo, would not bring more than $80, while good rice land sold for $200. A second grower of bamboos near Kyoto, who ships for the export trade from Kobe, informed the writer that the culture in his province of *Phyllostachys quilioi* yields a net income of about $40 per acre, while *P. henonis* brings in only about $30. Five years ago the black bamboo brought in a profit of $200 per acre, but now scarcely nets $50. Rice culture in this region, according to Mr. Tsuboi, barely pays more than for the cost of labor and manure, the former reckoned at 35 to 40 sen, or 17½ to 20 cents gold, a day. All of these figures, however, have no practical bearing on the profits of bamboo growing in America, where a market for the culms can only be made after a constant reasonable supply has been assured.

The cost of the attention which is necessary in order to grow bamboos is so much less than that required for rice growing, suitable land is so much cheaper, and so much less risk is run from bad weather, that the statement that it is the best paying culture in Japan seems correct, and such inquiries tend to confirm it.

CULTURE OF THE EDIBLE BAMBOO.

Only one species of bamboo is commonly grown in Japan for food, and this is the largest one (*Phyllostachys mitis*), known as "Moso." It was introduced from China, where its value as a food plant has been known for centuries, and its common name indicates its origin.[a] One other sort, *P. aurea*, is also said to have edible shoots, but those of the remaining kinds are understood to be too bitter to be eaten.

The method of cultivating this species differs from that described for the timber sorts. The best soil is a more friable one, and if not naturally with a good admixture of sand it must be top dressed every year with 1 inch of light sandy loam and a mulching of straw or grass and weeds cut from the meadow. The young plants are set out more sparsely than if designed for timber, not more than 120 to the acre. Liquid manure is given freely to the newly set out plants, and as long as they are grown for their edible shoots large amounts of rich fertilizer containing much soluble nitrogen must be supplied them. In Japan the cost of the fertilizer is the principal expense of cultivation. In five years, if the transplanted mother plants are of good size, they should yield shoots large enough for sale, but ten years are required to bring the plantation into a profitable bearing condition. Weeding is done more carefully than in timber groves, though for the first five or six years all the shoots which come up are allowed to stand; but later, when the plantation is established, all small-sized ones are promptly removed as soon as they appear above ground. In order to obtain a supply of fresh culms a regular system in cutting out the old ones is followed. A definite number of selected stems, as soon as they are fully grown, are marked with the year of their production, and nine years later all of those bearing the same date are cut out. Each spring the same number (about 80 per acre) of new culms are spared from being dug out when small for market, and each autumn a similar

[a] Moso is the name of one of the twenty-four paragons of Chinese filial piety. The story is the case of a boy whose widowed mother fell ill and longed for broth made of young bamboo shoots. The shoots not being procurable in winter, his devotion was such that he went out in the snow to dig for them. The gods rewarded his devotion by causing the shoots to grow suddenly to an unheard-of size. Japanese artists are fond of illustrating their works of art with drawings of the boy Moso.

number of 9-year-old stems are cut and sold for timber. These are only a small proportion of the total number of bamboos on an acre, for this ranges from 640 to 680. If this system of thinning out is followed a plantation may be kept in bearing almost indefinitely. Near Kyoto the practice is followed of cutting off the top of every shoot left standing, before it is fully mature, to a height of from 12 to 14 feet. This prevents the wind from moving the culms too much and induces the formation of a bushy mass of luxuriant foliage and a great number of medium-sized shoots, which are more profitable than the few larger-sized ones that result if the mother plants are not topped.

The tenderest shoots and those which bring the highest prices are the ones dug up before their tips have pierced the surface of the soil. These bring, early in the season, as much as 1 yen per "kwan" (about 6 cents gold per pound), while the later product must sometimes be disposed of for a tenth of this price. The market season in Tokyo begins in December and closes in June. Although bamboo shoots are very nutritious, they are not easily digested, and many Americans do not like them for this reason. Old residents in Japan, however, often grow very fond of them and have adapted them to their Western menu.

Miss Fanny Eldredge, of Yokohama, has very kindly furnished the following recipes for cooking bamboo shoots:

1. *Bamboo sprouts with cream sauce.*—These sprouts are cut when about a foot above the ground, by digging down to the rhizomes which bear them. After being gathered, the outside sheaths are removed and the shoots are soaked for half an hour in cold water. They are then cut in thin slices, about 3 inches long by 1 inch square, and thrown into boiling water containing a small teaspoonful of salt, and are boiled from an hour to an hour and a half, or until tender. The pieces are then drained and a white sauce is poured over them, which is made in the following way: To a half pint of cream or milk add a teaspoonful of butter; season with salt and black pepper. Allow this to boil up and serve at once. If desired, this sauce may be thickened with flour.

2. *Bamboo shoots in butter.*—Slice and cook as in the previous recipe, until tender. Into a saucepan put three tablespoonfuls of butter, seasoned with pepper, salt, and a little chopped parsley. When heated, put in the bamboo. Shake and turn until the mixture boils; then lay the bamboo on a hot platter, pour the butter over it, and serve at once.

3. *Bamboo shoots, Japanese style.*—Slice and cook the bamboo until tender, as in recipe No. 1; then put into a sauce made as follows: Take one coffee cup full of soy sauce (this is the basis of Worcestershire sauce and obtained only at Chinese or Japanese grocers or at some of the largest groceries in our large cities), one-fourth cupful of water, one heaping teaspoonful of sugar; let boil for half an hour in this sauce, and serve.

DIFFERENT SPECIES OF BAMBOOS.

The bamboo family is a large one and scattered over a great portion of the warmer and mountain regions of the globe, and, owing to the fact that the plants so infrequently bloom and that their classification depends upon the characters of the flower, it is not a very well-known group of plants. The monograph by Munro[a] is one of the most comprehensive attempts to give in one book descriptions of all of the known species. Of the hundreds of described forms only a small proportion are of much economic importance, and of these only a few are hardy. When the interior of China, the slopes of the Himalayas and Andes, and the mountains of the Malay Archipelago have been searched over for valuable hardy forms, the comparatively short list of species suitable for introduction will doubtless be largely increased. Anyone wishing to know what a large territory there is to search over for hardy bamboos and how many remain to be introduced and tested, will find these subjects discussed in a very interesting chapter called, "Future possibilities," in Mr. Mitford's book, "The Bamboo Garden." Nor should attention be confined to the hardy forms, when the tropical species are so many and various and have been so little studied from an economic standpoint. There are forms in Burma which could doubtless be introduced with great advantage into the Philippines, and species from the semi-tropical regions of China which are worthy of establishing in Hawaii. In fact, the more familiar one becomes with the bamboo question the truer does Mr. Mitford's statement, from the æsthetic standpoint, appear, that "we have only touched the fringe of what we may hope to achieve in the decoration of our wilderness gardens with the grace of these royal grasses."

At present, only a limited number of forms are eligible for introduction into the United States, and the majority of these are found in Japan.

The following popular descriptions of the more important economic sorts are given to assist in determining those common species which may be introduced in the near future, or which are already growing in America. The nomenclature followed is that given by Mr. Mitford in his "Bamboo Garden," except in such species as are not included by him, when Sir Ernest Satow's work, "The Cultivation of Bamboos in Japan," is followed. This is not an attempt to clear up the nomenclature of these badly mixed species.

The different common species of Japanese bamboos which resemble each other have been so often taken for one another that a convenient method of telling them apart is a very desirable thing. Such a method Sir Ernest Satow has drawn attention to in his book. It consists in comparing the forms and markings of the sheaths that surround the young shoots and in the leaf-like appendages or pseudophylls which are borne at their tips. He has published colored plates to illustrate

[a] Monograph of the Bambusaceæ, including descriptions of all the species. London, 1870, 157 pp.

these characters. The difficulty in using them, however, is that the sheaths are only obtainable in the season when there are young shoots. Mr. Mitford points out that the form and coloration of the winter buds in the axils of the branches, from which new branches develop, are important means of distinguishing the species. The characters which determine whether a bamboo belongs to the *Bambusa*, *Phyllostachys*, or *Arundinaria* genera, which are all it is necessary to consider here, are unfortunately largely floral ones and for practical purposes nearly useless. The genus *Bambusa* belongs to a section (*Bambusæ veræ*) in which the flowers have six stamens, while *Phyllostachys* and *Arundinaria* both belong to the *Triglossæ* section, where the flowers have three stamens. *Arundinaria* is distinguished from *Phyllostachys* by having round stems, while those of the latter are grooved or slightly flattened on one side. The sheaths in *Arundinaria* remain attached much longer than in *Phyllostachys*, as a rule those of the latter genus dropping off as soon as the culms are mature.

Phyllostachys Mitis, A. & C. Rivière.

(Japanese name: "*Moso-chiku*" or "*Mouso-chiku.*")

The largest hardy species in Japan, growing to a height of over 50 feet and producing, not uncommonly, culms over 6 inches in diameter. In England specimens have been grown to a height of 19 feet and a diameter of 1½ inches. *The culms are gently curved shortly after leaving the ground*, while those of other sorts with which it might be confused rise straight from the base. (Compare figs. 1 and 3, Pl. IV.) Its sheaths are of a light-brown color, *marked with dark umber-brown blotches and round dots* and covered with bristles. The pseudophyll is broad at the base, tapers to a point, *but is not wavy in outline.* The sheath spreads right and left from the base of the pseudophyll and is fringed throughout with hairs, which are straight when they lie between the pseudophyll and the stem, but curled on the right and left sides where they are free to develop. The internodes are generally shorter than those of the other large species and *the leaf sheaths are fringed at the insertion of the leaf with a number of rather course hairs.* The branch buds are purplish brown and strongly marked. The leaves vary from 1 to 6 inches in length and are too variable to be convenient characters for quick determination. This is the great edible bamboo of Japan and China, the method of cultivation of which has been described. It is not as hardy in England as *Phyllostachys quilioi* and *P. henonis.*

Phyllostachys Quilioi, A. & C. Rivière.

(Japanese name: "*Madake.*")

The second largest hardy species, growing to a height of 30 to 40 feet in Japan and 18 feet in England, with a diameter of 4 inches and 1¼ inches, respectively. The great timber bamboo of the Japanese.

The culms rise straight from the rhizome, and the branches are proportionately long, compared with the height of the stem.

Its sheaths are marked with *purple or reddish blotches, which are much more pronounced in character than those of the preceding species, and the pseudophyll has a wavy outline.* The branch buds have green bases, and only the tips are brown. The new shoots appear above ground in Japan a month later than those of the following species (*P. henonis*), that is, in June. The internodes are proportionately longer than those of *P. mitis*, but the leaf sheaths are fringed with long hairs, as they are in that species. The leaves vary in length from 2 to 8 inches, but are proportionately broader, according to Mitford. This species is hardy in England and has a more vigorously spreading rhizome than that of *P. mitis* or *P. aurea.*

Phyllostachys Henonis, Mitford.

(Japanese name: "*Hachiku.*")

A somewhat smaller kind of bamboo than the preceding two species. Considered by Mitford the prettiest one cultivated in England. Height in Japan from 20 to 30 feet, with a maximum diameter of a trifle over 3 inches. In England specimens 14 feet high and one-half inch in diameter occur. After *P. mitis* and *P. quilioi* the commonest timber form in Japan. Culms rise straight from the base. *Sheaths are a straw color, with few or no spots of any kind and with a distinctly wavy pseudophyll* like the blade of a Malay *kris.* New shoots appear before those of *P. quilioi*—that is, in April and May. The leaf sheaths are fringed (at least on young plants) with delicate hairs, which are *neither so long nor bristlelike as those in P. mitis and P. quilioi.* Branch buds are a pale yellowish-green. The pipe is thinner walled than that of *P. quilioi*, and its use in the arts is restricted because of the inferior quality of the wood. The rootstock is said to run freely in England, where it has proved hardy.

"Madaradake" or "Ummon-chiku."

A form closely related to *P. henonis*, which is distinguished by having dark blotches on its culms that are presumably caused by some as yet undetermined species of fungus. These spots are regularly present on almost all internodes and give to the stems a very decorative appearance, making them much sought after for fancy furniture. The extent and beauty of these blotches vary with the amount of shade which the plants are given and the kind of soil upon which they are grown. The best location is said to be a moist river bottom, and the less direct sunlight that is permitted to strike the young shoots when in growth the better. A rare sort, except in certain localities in Japan. Some of the best groves the writer has seen are in Hikone, in the province of Mino, on Lake Biwa.

PHYLLOSTACHYS NIGRA, Munro.

(JAPANESE NAMES: "*Gomadaké*," "*Kuro-chiku*," or "*Kurodaké*.")

The black bamboo is not as generally grown in Japan as the three species just mentioned, but it is nevertheless an important culture. Formerly more money was made out of it than has been the case in recent years, because the foreign demand, it is said, has fallen off.

It is a smaller species than the other timber sorts, seldom growing over 20 feet high and 1½ inches in diameter.

The culms when young are covered with dark-brown to purple spots, which spread as it grows older until the whole culm becomes dark-brown, almost black, except just below the nodes, where there is an ash-gray line. This dark color at once distinguishes the species from all other Japanese sorts. Branch buds are brown, mottled with black. There is a great variation in the intensity of this dark color of the culms, and this is said to vary with the kind of soil upon which the plants are grown and the amount of sunlight to which they are exposed. There are, however, at least two varieties of this species, one with much more intensely brown culms than the other. Mr. Mitford calls the lighter sort *P. nigro-punctata*, and remarks that it is hardier than *P. nigra*, but not so pretty. Light, hillside soil is claimed as better adapted to the production of intense color than rich alluvium, and it is found necessary to renew old plantations, in order to prevent the color from fading out.

This is one of the hardiest forms grown in England, attaining in exceptional cases 20 feet in height, and it is certainly one of the most decorative kinds. Nothing could exceed the delicate beauty of the groves of this species which are to be seen near Kyoto. Their dark stems, ash-gray nodes, and light-green foliage make them unique among decorative plants. (See Pl. I.)

The uses of this species are limited to the manufacture of furniture, numerous household articles, and fancy fishing poles, for all of which these black bamboos are peculiarly suited.

PHYLLOSTACHYS CASTILLONIS.[a]

(JAPANESE NAME: "*Kimmei-chiku*.")

The golden-striped bamboo is one of the most decorative forms of the group. It is not easily confused with other Japanese sorts when its characters are fully developed, for each culm is of a beautiful golden-yellow color, striped with brilliant green. The leaves also are variegated with stripes of green and white. The contrast between the golden yellow of the stems and the green stripes on the young

[a] No authority is given by Mitford for this name, and the author has been unable as yet to work out its correct name. The nomenclature of the bamboos needs working over.

shoots is one of the prettiest effects imaginable. The species grows occasionally over 30 feet high in Japan and specimens 5 to 6 feet high are already found in England, where the species has withstood a temperature of 24 degrees of frost or 8° F. It is not a common species even in the gardens of Japan, and Mr. Mitford says it is uncommon in England. Very young plants sometimes show only slight traces of the variegation on the stems, but develop this character later.

Mr. Tsuboi, who has the most exceptional taste in bamboos, and in the dwarfing of which he is an acknowledged connoisseur (see Pl. VII, fig. 1), suggested planting a mixture of this golden bamboo with the black species, *P. nigra*. As a rule, mixtures of bamboos are said to be objectionable, but such a mingling of golden and black stems is worthy of an experiment.

Phyllostachys Aurea, A. & C. Rivière.

(Japanese names: "*Hotei-chiku*," "*Hôrai-Chiku*," or "*Taibo-Chiku*.")

A smaller species than *P. mitis* or *P. quilioi*, but attaining in England a height of 14 feet and a diameter of culm of over three-fourths of an inch. In Japan, culms have been observed over 1½ inches in diameter. It is not a golden bamboo, as its name implies, its stems being about the color of *P. mitis*. The distinguishing characteristic is that the first 5 or 6 internodes near the ground are very short, bringing the internodes, or joints, close together, often only a few inches apart. These joints are not, as in *P. heterocycla*, set at an angle to the direction of the stem, but are generally parallel to each other and quite horizontal. Branch buds are variable in color, but pale. Mr. Mitford remarks that this species should be planted in large, bold masses for good landscape effect, for if single plants are set out they send up shoots only near the mother culm and produce a switch-like effect. The shoots of this species are edible, according to the Japanese books, and are of even better flavor than those of *P. mitis;* but this variety does not appear to be grown for food.

Phyllostachys Bambusoides, Sieb. & Zucc.

(Japanese name: "*Yadake*.")

The arrow bamboo is that of which the stems are still employed in the manufacture of the fine Japanese arrows used generally for archery purposes. The plant is still a rare one in England, and Mitford says that other sorts are sometimes sold by Japanese nurserymen under its name. It is not very commonly seen in gardens, so far as observed, even in Japan, and the arrow makers, it is said, get their main supply of stems from wild plants. There are some of these manufacturers in the town of Shizuoka, but the demand for arrows is so small that they are doing a poor business. This species is distinguished from others by the fact that it does not have an actively creeping rootstock. Each plant forms a separate small clump by itself. The branches are shorter than the internodes and the middle branch of the three is longest, whereas in other bamboos the middle branch is the shortest—sometimes wanting. Clumps of this form grow to 10 or 12 feet in height in Japan, with a diameter of little over three-fourths of an inch. The internodes are long, and the sheaths, although withering the first year, do not fall off until the following year. They are bright green in color, with a purple edging. The leaves are large, sometimes over 12 inches long by $1\frac{1}{4}$ inches broad, and are borne in fours, fives, sevens, or eights. The hardness of the culms, their small cavity, and the smoothness of the nodes, as well as their small size, are characteristics that well adapt them for arrow making. This is believed to be a hardy species, and it is quite unlike the ordinary bamboos in appearance.

PHYLLOSTACHYS MARLIACEA, Mitford.

(JAPANESE NAMES: "*Shibo-chiku*" or "*Shiwa-chiku.*")

The "wrinkled bamboo" is easily distinguished from all other kinds by the fact that its culms are longitudinally channeled with shallow grooves. It is a low-growing species compared with *P. quilioi*, which it otherwise resembles, not being commonly over 12 to 14 feet high, even in Japan. It is a rare kind, and its culms are used occasionally, it is said, for decorative woodwork in the special rooms which in many Japanese houses are kept sacred for the tea-drinking ceremony. A beautiful and hardy form.

ARUNDINARIA JAPONICA, Sieb. & Zucc.

(JAPANESE NAME: "*Métaké*" or *Médaké;*" not "*Makade.*")

A well-known bamboo in Europe, where it is not very highly thought of by some, but is praised as a valuable decorative plant by others. A form distinguishable by its persistent sheaths which, instead of falling off, like those of the genus *Phyllostachys*, remain attached until they become frayed out and split to pieces. These ragged sheaths give to clumps of the plant an untidy appearance. The culms are round and without any groove or flattening on one side, as is the case with the Phyllostachides. The pseudophylls of the ordinary sheaths are very narrow, sometimes not over an eighth of an inch wide, and from 1 to 2 inches long; but those of the topmost sheaths develop into true leaves. The leaves themselves are large, 8 to 12 inches by $1\frac{1}{2}$ to 2 inches. This is said to be the hardiest species in Japan, growing as far north as the island of Hokkaido, where the temperature falls below zero Fahrenheit. Its culms are extensively used for fan making, and millions of cheap paper-colored fans are made every year from the stems of this species. River banks and the margins of ponds and canals are eminently suited to its growth, and the overflowed lands of the Colorado River in Arizona might be planted to advantage with this species. This bamboo is one of the few that has flowered and fruited in Europe. According to Mr. Mitford, specimens in the Bois de Bologne in Paris, and simultaneously all over France and in Algiers, bloomed and produced fruit in 1867 or 1868.

Arundinaria Simoni, A. & C. Rivière.

(Japanese name: "*Narihiradake.*")

This species is easily distinguished by its broad, persistent sheaths of a plain straw color that fall off only after the culms have attained maturity. (Pl. V, fig. 1.) It is the tallest of the hardy arundinarias which are grown in England, the culms attaining a height of 18 feet and a diameter of an inch. The shoots appear from midsummer until late in the autumn, and Mr. Mitford remarks that many do not mature sufficiently to stand the English winters. The sheaths nearest the ground are short, though long enough to overlap the internodes, but those of the upper joints, although 8 to 10 inches long, do not exceed the internodes in length. They are at first of a fine green color, shading into purple, which soon fades, however, to a dull yellow. These prominent sheaths, which are thick, stiff, and beautifully glazed on the side next the culm, will easily distinguish this arundinaria from any other common Japanese form. The species has flowered and fruited in England, and it is quite universally grown in English gardens. A long description of it is given by Mr. Mitford in "The Bamboo Garden."

Arundinaria Hindsii, Munro.

(Japanese name: "*Kanzan-chiku.*")

The Kanzan-chiku is a very common garden plant about Tokyo, and clumps of it are to be found in many of the farmyards in central Japan, where the culms grow to a height of 18 feet and attain a diameter of over $1\frac{1}{2}$ inches. This species forms pretty clumps, with a fine grass-like foliage, and although little farm use is made of it, it is worthy of trial as an ornamental. Its hardiness has not been demonstrated in England, but it seems likely to prove as hardy as forms like *P. mitis*. It is distinguished from the preceding arundinarias by its long, narrow leaves, sometimes 9 inches by five-eighths of an inch, according to Mr. Mitford. The sheath is provided with a reddish margin toward the tip.

Arundinaria Hindsii, var. Graminea.

(Japanese name: "*Taimin-chiku.*")

A sort similar to the foregoing, but with considerably narrower leaves and a longer, narrower sheath, with no evidences of a brown margin.

Bambusa Veitchii, Carr.

(Synonym: *Arundinaria veitchii.* Japanese name: "*Kokumazasa;*" sometimes only "*Kumazasa.*")

The Kumazasa, by which is generally meant *Bambusa palmata*, and this *B. veitchii* are sometimes confused. The latter may be distinguished by the fact that its leaf margins wither in late autumn and make the plant look as if it were variegated. *B. veitchii* is furthermore, as a rule, only about 2 feet high, whereas *B. palmata* grows to 5 feet in height. The sheath of *B. veitchii* is said by Sir Ernest Satow to be longer and more persistent than that of *B. palmata*. The leaves of *B. veitchii* are much smaller than those of its taller relative and warrant the name of "Kokumazasa," or lesser bamboo. This species is suitable for lawn planting and is used by the Japanese to plant under their pine trees and to cover with a thick mat of green foliage a sloping hillside or embankment, for both of which purposes it is admirably adapted (Pl. V). It must be kept from spreading into cultivated ground by means of a broad ditch, 2 feet deep and 1½ feet wide. The variegated effect produced by the dead margins of the leaves after being touched by frost is striking, though not very attractive.

Bambusa Palmata, Hort. Ex. Kew Bull.

(Japanese name: "*Kumazasa.*")

A much larger species than the preceding and with leaves 12 to 13 inches long instead of 5 to 6 inches. Altogether one of the most effective plants for embankments, as it covers them with a mass of broad leaf surface which is very attractive. Its rhizomes are said to be good sand-binders. Large patches of this plant on a lawn or hillside are striking objects of interest. Caution must be exercised to prevent the rhizomes from invading cultivated fields. This can be done by ditching, as has been described for *B. veitchii*.

Bambusa Quadrangularis, Fenzi.

(Japanese names: "*Shiho-chiku*" or "*Shikaku-daké.*")

The square bamboo is unlike any other Japanese species in the possession, when fully grown, of square culms. These square stems are often not apparent on young small shoots, but the older ones are sure to show this character. The squareness of these culms is aptly compared by Mr. Mitford to the square stems of the Labiates. Small groves of this bamboo are to be seen not far from Yokohama, and the writer has seen stems among one of these groves that were about 20 feet high, while Mr. Mitford says the plant grows to 30 feet near Osaka. The sheath is very thin and delicate and more open than in most bamboos, gaping from the base and leaving the greater part of the internode uncovered. The wood of this species is too weak to make it of any great value, and its sensitiveness to frost is too great to enable one to class it among the hardy sorts. It is, however, a decorative plant and worthy of repeated trials in the frostless regions of America. It is said that roots will form easily from the lower nodes of the square bamboo if the portion bearing these nodes is buried in the soil. This would facilitate propagation if the statement proves correct.

Bambusa Vulgaris, Schrad.

(Japanese name: "*Taisan-chiku.*")

A species growing in Satsuma, the southern province of Japan, but which is not hardy at Yokohama. It is propagated differently from the hardy sorts, as new shoots are borne from the base of the culm as well as from the rhizome. Short culm bases, without rhizomes, are potted and easily transported from Satsuma to Yokohama, where new branches appear from the nodes. This species is said to be easy to propagate because of this character, but it will probably have a chance to succeed in the United States only in subtropical Florida and Texas, where it will require a good soil, rich in humus.

"Shakutan."

"Shakutan" is the name of a very pretty species which is reported to grow in the northern island of Japan and to be perfectly hardy. The writer saw plants under this name in the Yokohama Nursery Company's grounds. They were very distinct from *B. palmata*, and dried specimens were sent to Mr. Makino in Tokyo for determination. The species is probably related to *B. palmata*, but the broad, large leaves are mostly situated near the tip of the slender sheath-covered stem, which rises from the ground with a characteristic curve, and is bare of leaves for several feet from the ground.

Plate V, fig. 3, shows a clump of what appears to be the same species, from Tosa, one of the southern islands of Japan, which was growing in Mr. Tsuboi's garden under the name "Hanchiku." The culms are almost covered with the light-colored persistent sheaths from the ground to the leaves. The stems are not over one-fourth to three-eighths of an inch in diameter, and are about 5 feet high.

PLATES.

DESCRIPTION OF PLATES.

PLATE I. A commercial grove of the black bamboo (*Phyllostachys nigra*) growing at Kaiden, Shinkotari, near Kyoto, the property of Mr. Denkichi Fujibayashi. Age unknown, but probably more than 30 years old. Photographed by Yendo.

PLATE II. A well-kept forest of *Phyllostachys quilioi* growing on good soil, showing an open drainage ditch in foreground and the thick mulch of leaves and straw which cover the ground. Age probably over 50 years. Photographed by Yendo.

PLATE III. Bamboo forests. *Fig. 1.*—A well-kept forest of *Phyllostachys quilioi* growing on poor soil filled with gravel Weeding has not been as recently done as in that part of the forest shown in Pl. II. The two photographs from which these plates were prepared were taken from points not 20 yards apart in the forest of Mr. Isuke Tsuboi, of Kusafuka. Photographed by Yendo. *Fig. 2.*—A badly kept forest of timber bamboo (*Phyllostachys quilioi*) growing on good soil adjacent to the well-kept forest shown in Pl. II. This shows the effect of not weeding, thinning out, or fertilizing. Photographed by Yendo.

PLATE IV. Bamboo groves in Japan. *Fig. 1.*—A hillside grove or forest of the edible species (*Phyllostachys mitis*) 20 years old, showing large size of the culms. *Fig. 2.*—A grove of the same species over 100 years old near Tokyo. The bundle of barley straw shown on the right will be used for mulching purposes. *Fig. 3.*—A 12-day-old shoot of *Phyllostachys quilioi* in a forest of the same species on Mr. Tsuboi's place at Kusafuka.

PLATE V. Bamboo groves in Japan. *Fig. 1.*—Clump of *Arundinaria simoni*, showing the persistent characteristic sheaths. *Fig. 2.*—Grove of *Phyllostachys quilioi* on Mr. Tsuboi's place at Kusafuka. Age unknown, but probably more than 50 years old. *Fig. 3.*—Plat of a species of bamboo called by Mr. Tsuboi "Hanchiku," from Tosa Island, which has not been determined botanically so far as known. An exceedingly pretty, decorative form, somewhat like *Phyllostachys palmata*.

PLATE VI. Bamboo plants. *Fig. 1.*—A young black bamboo plant of which the rhizome, to be seen on the left, has died. The rosette of leaves still remains alive, but no young shoots are formed. This specimen was dug in Mr. Tsuboi's garden at Kusafuka. Photographed by Yendo. *Fig. 2.*—Properly dug young plant of black bamboo ready to transplant, showing several inches of rhizome on both sides of the base of the stem, which is necessary for the production of new shoots. This specimen was dug under Mr. Tsuboi's direction and represents his idea of how a plant should be prepared for transplanting if dug late in the season. Photographed by Yendo. *Fig. 3.*—Rhizome or underground stem of bamboo (*Phyllostachys quilioi*), showing young shoots and roots springing from the nodes. Dug in June. If dug in winter, the buds would all be in a dormant condition. Photographed by Yendo.

PLATE VII. Bamboo scenes. *Fig. 1.*—Dwarf bamboos at Kusafuka. *Fig. 2.*—Embankment on top of a wall in a city street in Tokyo planted with *Bambusa veitchii*. *Fig. 3.*—Young shoot showing effects of the bamboo culm-boring larva. Sawdust on outside of shoot affords evidence of presence of larva within. *Fig. 4.*—Longitudinal section of young shoot showing the culm-boring larva inside one of the segments. Photographed by Yendo.

PLATE VIII. Bamboos in California. *Figs. 1 and 3.*—Rows of *Phyllostachys quilioi* (?) growing 25 feet tall in the grounds of a nursery company at Niles. Watered twice a year with 2 inches of water each time. This species is called *Bambusa striata* by Mr. Rock. *Fig. 2.*—Plant of *Phyllostachys quilioi* (?) which was set out two years ago in the grounds of a nursery company at Niles.

O

A WELL-KEPT FOREST OF TIMBER BAMBOO (PHYLLOSTACHYS QUILIOI) ON GOOD SOIL.

FIG. 1.—A WELL-KEPT FOREST OF TIMBER BAMBOO (PHYLLOSTACHYS QUILIOI) ON POOR SOIL.

FIG. 2.—A BADLY KEPT FOREST OF TIMBER BAMBOO (PHYLLOSTACHYS QUILIOI) ON GOOD SOIL.

FIG. 1.—A HILLSIDE FOREST OF EDIBLE BAMBOO, 20 YEARS OLD.

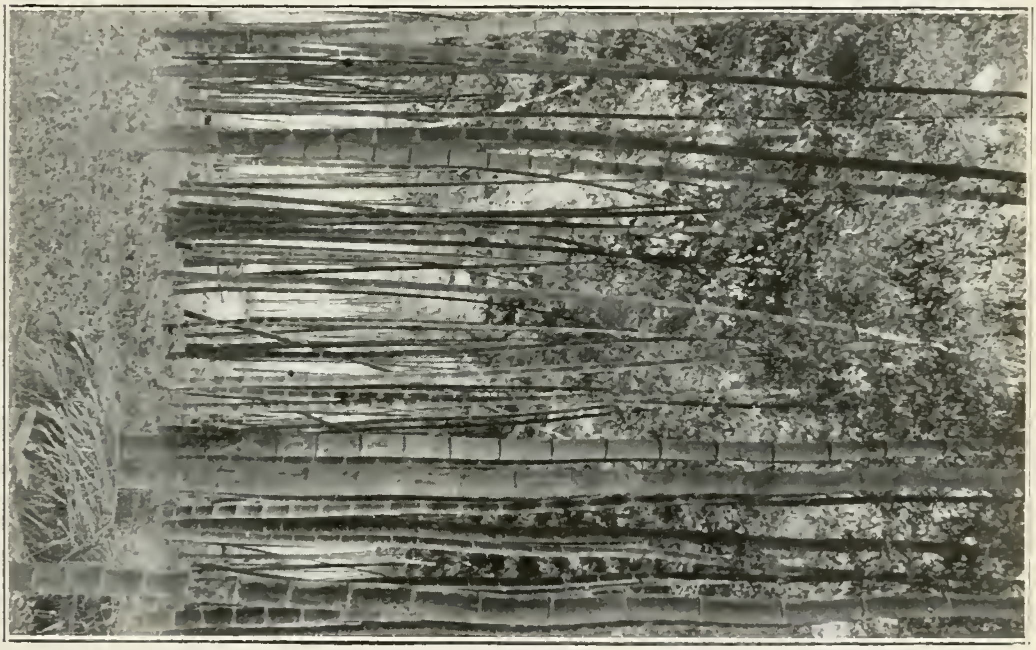

FIG. 2.—A GROVE OF EDIBLE BAMBOO, MORE THAN 100 YEARS OLD.

FIG. 3.—TWELVE-DAY-OLD SHOOT OF PHYLLOSTACHYS QUILIOI IN FOREST.

BAMBOO GROVES IN JAPAN.

Fig. 1.—Clump of Arundinaria simoni, Showing Persistent Leaf Sheaths.

Fig. 2.—Grove of Phyllostachys quilioi, Age Unknown.

Fig. 3.—Plot of Species of Bamboo Called Hanchiku.

BAMBOO GROVES IN JAPAN.

FIG. 1.—BLACK BAMBOO PLANT, SHOWING THE EFFECT OF THE DEATH OF THE RHIZOME.

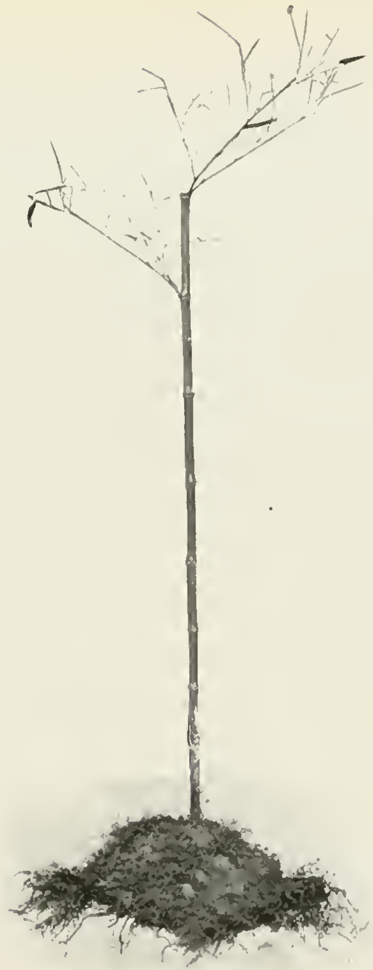

FIG. 2.—PROPERLY DUG YOUNG PLANT OF BLACK BAMBOO.

FIG. 3.—RHIZOME OF BAMBOO WITH YOUNG SHOOTS AND ROOTS SPRINGING FROM NODES.

FIG. 1.—A FEW DWARF BAMBOOS.

FIG. 2.—EMBANKMENT OF BAMBUSA VEITCHII IN TOKYO.

FIG. 3.—SAWDUST ON SHOOT, INDICATING PRESENCE OF CULM-BORING LARVA.

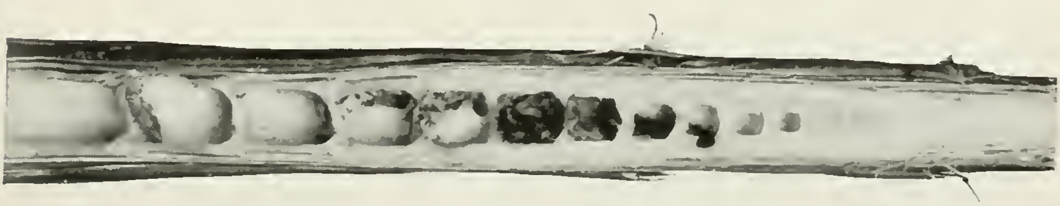

FIG. 4.—LONGITUDINAL SECTION OF SHOOT, SHOWING CULM-BORING LARVA.

FIG. 1.—PHYLLOSTACHYS QUILIOI (?) AT NILES, CAL.

FIG. 2.—CLUMP OF PHYLLOSTACHYS QUILIOI THE SECOND YEAR AFTER TRANSPLANTING.

FIG. 3.—PHYLLOSTACHYS QUILIOI (?) AT NILES, CAL.

BAMBOOS IN CALIFORNIA.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 44.

B. T. GALLOWAY, *Chief of Bureau.*

THE BITTER ROT OF APPLES.

BY

HERMANN VON SCHRENK,
SPECIAL AGENT IN CHARGE OF THE MISSISSIPPI VALLEY LABORATORY,

AND

PERLEY SPAULDING, SPECIAL AGENT.

VEGETABLE PATHOLOGICAL AND PHYSIOLOGICAL INVESTIGATIONS.

ISSUED JULY 18, 1903.

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1903.

BULLETINS OF THE BUREAU OF PLANT INDUSTRY.

The Bureau of Plant Industry, which was organized July 1, 1901, includes Vegetable Pathological and Physiological Investigations, Botanical Investigations and Experiments, Grass and Forage Plant Investigations, Pomological Investigations, and Experimental Gardens and Grounds, all of which were formerly separate Divisions, and also Seed and Plant Introduction and Distribution, the Arlington Experimental Farm, Tea Culture Investigations, and Domestic Sugar Investigations.

Beginning with the date of organization of the Bureau, the several series of bulletins of the various Divisions were discontinued, and all are now published as one series of the Bureau. A list of the bulletins issued in the present series follows.

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[Continued on p. 3 of cover.]

APPLES AFFECTED WITH BITTER ROT.

Inoculation from a canker.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 44.

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BUREAU OF PLANT INDUSTRY.

B. T. GALLOWAY, *Chief.*

VEGETABLE PATHOLOGICAL AND PHYSIOLOGICAL INVESTIGATIONS.

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[a] Detailed to Botanical Investigations and Experiments.

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
BUREAU OF PLANT INDUSTRY, OFFICE OF THE CHIEF,
Washington, D. C., April 8, 1903.

SIR: I have the honor to transmit herewith a paper on "The Bitter Rot of Apples," by Dr. Hermann von Schrenk, Special Agent in Charge of the Mississippi Valley Laboratory, and Perley Spaulding, Special Agent, Vegetable Pathological and Physiological Investigations, and respectfully recommend that it be published as Bulletin No. 44 of the series of this Bureau.

This paper was prepared under the direction of and was submitted for publication by the Pathologist and Physiologist. The illustrations, which comprise nine half-tone plates and nine text figures, are an essential and important part of the paper.

Respectfully,

B. T. GALLOWAY,
Chief of Bureau.

HON. JAMES WILSON,
Secretary of Agriculture.

PREFACE.

For the past four or five years the bitter rot of apples has been the cause of heavy loss to growers and handlers of this fruit. As stated in our report for 1901, the president of the National Apple Shippers' Association estimated that the damage to the apple crop of the United States in 1900 from bitter rot was $10,000,000. In some orchards there was a total loss of fruit; in others from one-half to two-thirds of the crop was destroyed. The disease is especially severe in the Mississippi Valley and the States along the Ohio River. At the request of numerous growers this Bureau undertook extensive investigations to determine more definitely the life history of the fungus causing bitter rot with the hope of discovering a more effective method of holding it in check. The report presented herewith contains a general account of the history of the disease, a description and life history of the fungus causing it, and some facts which have been recently discovered in regard to the mode of life of the parasite.

During the year 1901 cooperative experiments, conducted along lines suggested by this Bureau, were carried on with the Illinois Experiment Station, but during the last season the work was conducted independently by both the station and the Department. Cooperative experiments on the control of this disease were started the past year with the Missouri Fruit Experiment Station, and will be continued with this station and fruit growers in various apple sections during the present season.

ALBERT F. WOODS,
Pathologist and Physiologist.

OFFICE OF THE PATHOLOGIST AND PHYSIOLOGIST,
Washington, D. C., April 7, 1903.

CONTENTS.

ILLUSTRATIONS.

PLATES.

TEXT FIGURES.

THE BITTER ROT OF APPLES.

INTRODUCTION.

The bitter rot or ripe rot of apples has for many years formed one of the most serious enemies of this fruit. It made its first appearance in the United States before 1867, according to Curtis's catalogue, but it was not specifically described until 1874, when M. J. Berkeley and M. A. Curtis published the first descriptive notice concerning its occurrence in America. With the increasing number of apple orchards throughout the central belt of States, its range and destructive action have steadily increased.

The bitter rot is a disease of the ripening fruit, which appears late in the summer, affecting whole orchards at once and destroying vast quantities of fruit when it is almost ready for marketing. Estimates of the loss resulting to apple growers from the ravages of the bitter rot in various sections of the country have been made repeatedly.

The bibliography beginning on page 46 of this bulletin gives in full the titles to which the short citations of authorities in the text of this paper may be referred.

A few statements from various sources will show what this pest is capable of doing:

> This orchard that appears so vigorous and healthy is almost worthless. Last year it had at least 1,000 bushels of apples on, and the proprietor did not get a bushel of winter apples. The bitter rot blasts them like the breath of ruin, and the promise of spring ends in disappointment and decay. * * * This orchard was in its prime from the time it was 8 until it was 18 or 19 years old. For ten or eleven years it gave most bounteous returns and produced wagonloads of the finest fruit. It then began to decline. The fruit commenced to speck, and the evil increased until the trees are little more than an incumbrance on the ground. (Murray, 1870.)

An Arkansas man relates his experience as follows:

> The man from whom I purchased my place told me that the Fameuse had always been subject to the rot. For the last three years the disease has steadily increased, so that this year (1887) my old orchard of 75 trees will not yield 25 bushels of sound apples. (Galloway, 1887.)

In 1900 it was estimated that the loss in four counties of Illinois for that season was $1,500,000. (Burrill and Blair, 1902.)

The Pathologist and Physiologist of the Bureau of Plant Industry of the U. S. Department of Agriculture in 1901 says:[a]

> The losses caused by bitter rot in the Middle States often amount to half or three-fourths of the entire fruit crop, single large growers sometimes losing 10,000 barrels of apples. One firm estimated that their losses in 1900 on apples bought in the orchard in Missouri alone amounted to $20,000 to $30,000, and orchards which in midsummer promised a yield of 25,000 barrels of choice apples produced only about 5,000 barrels of indifferent fruit, owing to this disease. The president of the National Apple Shippers' Association estimated that the damage to the apple crop of the United States in 1900 from bitter rot was $10,000,000.

In some years the destruction was so great as to cause many fruit growers to abandon the business, and instances have been known where men have leased their bearing orchards at $5 per acre for periods of five years, preferring to be assured of that small amount rather than risk getting nothing from their trees because of the work of this fungus.

Older reports make mention of extensive destruction. Galloway reported in 1889 that "in certain places in Virginia, Kentucky, Tennessee, Missouri, and Arkansas our agents report this season a destruction of from 50 to 75 per cent of the crop."

Garman in 1893 stated that bitter rot probably caused more loss to Kentucky fruit growers than any other disease, and statements of this character have appeared from time to time and with increasing frequency in the reports of experiment stations and horticultural societies.

The sudden appearance of the disease at a time when the grower has spent time, money, and energy in producing a large crop, and the almost total destruction of the apples in a few days, causes the disease to be universally feared. It has probably done more to discourage apple growing in many regions than all other troubles, including both fungous and insect diseases combined.

In spite of the universal and destructive appearance of this disease, comparatively little had been accomplished until recently toward preventing or even checking the bitter rot, although its cause was clearly established by Berkeley in 1856, as described more fully hereafter, while other observers have given detailed accounts of spraying experiments. Ever since the experiment stations were established investigations have been conducted looking toward preventive measures. Many papers on the subject have been written, an idea of the number of which can be gathered by referring to the bibliography at the end of this Bulletin.

In the following pages a general account of the disease, a description of the fungus and its life history, and some facts which have recently been discovered in regard to its mode of life, etc., are presented.

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[a] Annual Reports, Department of Agriculture, 1901, p. 47.

HISTORICAL ACCOUNT OF THE BITTER ROT.

The early accounts of the bitter rot deal mainly with the fungus causing the disease, which for the present we will call by the name which it has held for so many years—*Glœosporium fructigenum* Berk. Rev. M. J. Berkeley described a fungus causing a ripe rot of grapes in 1854, which was probably the same as the bitter-rot fungus (see fig. 4). Two years later he described a fungus causing ripe rot of the apple, calling it *Glœosporium fructigenum* n. sp. He describes (1856) the disease (see fig. 5) as follows:

It (the apple) presented a spotted appearance externally as well as internally. * * * The spots were perfectly circular and well defined, and exhibited traces of vegetation. On cutting through the apple the flesh was found to be discolored in various places from the effects of incipient decomposition which was not confined to the surface but penetrated into the center of the fruit. * * * In a few days some of them (the spots) were studded with pearl-like specks bursting through the cuticle and swelling above it in the form of little flat cushions. Sometimes there was but a single speck in the very center, but more frequently there was a more or less perfect ring of satellites, * * * the cuticle was raised into little shining pustules, and a tendril of minute spores * * * was protruded through it.

In 1859 Berkeley described a fungus causing a disease of peaches and nectarines, which he called *Glœosporium laeticolor* n. sp.:

Nearly a month since we observed on the peaches little dark specks with a bleached center. * * * Two days ago he (the gardener) called our attention to its present condition. The specks were prevalent on the nectarines as well as the peaches. * * * It is of the disease, then, as developed on the nectarines more especially that we are speaking. * * * The white spot and the dark ring around it were most beautifully defined, seated in the center of a regular circular depression, the borders of which were pale, but not completely bleached like the center. The whole surface of the depression was studded with little salmon-colored warts, disposed more or less in circles, from the center of some of which, but especially of those in the bleached cuticle, a little curled tendril of salmon-colored spores was protruded. After a time, however, the several spots run together, and form a depression an inch or more across, still teeming with the red spores.

This fungus is apparently the same as *Glœosporium fructigenum* Berk. Berkeley in his description gives most of his attention to the fungus rather than to the disease caused by it, but we can very easily recognize the fungus of the bitter rot as being the same that he described.

In 1867 Rev. M. A. Curtis in a catalogue of the plants of North Carolina mentions a fungus, *Glœosporium versicolor* n. sp., as occurring upon rotten apples. This was the first use of the name, and also was the first record of the occurrence of a fungus causing bitter rot in this country, as far as can be determined. The bitter rot was very probably known at that time, and possibly quite extensively known, as the article by Murray in the Illinois Horticultural Society publication only three years later (1870) would seem to indicate. In 1874 Berkeley and Curtis published the first description of *Glœosporium versicolor* n. sp., so that the name really dates from 1874.

Practically all of the publications in regard to the bitter rot until 1887 were mere reprints of the articles already mentioned, and the disease was treated apparently as a rather uncommon one and not of much importance.

Galloway seems to have been the first to treat upon the subject of this disease from an economic standpoint, the first accounts dealing with the bitter rot as a destructive orchard disease being published by him in 1887. He called attention to the damage caused and the results of experiments made to check the disease. At that time the bitter rot had appeared in many States from the Atlantic seaboard to Kansas, and the destruction of apple crops was large. These experiments were followed by many others: Garman (1889), Galloway (1889), Jennings (1890), Curtiss (1890), Galloway (1890), Churchill (1890), Chester (1890), Garman (1890), and others. The results of these various experiments were very conflicting. A few investigators succeeded in totally checking the disease even after it had become well established, while others had no success whatever. In the more northern States experimenters seemed to succeed in checking the disease by spraying affected trees with the ordinary fungicides. In the region south of the fortieth parallel, i. e., in the territory extending from the eastern coast to Kansas, Indian Territory, and Texas, where the fungus seems to flourish best, it was found much more difficult to control the disease. Spraying experiments indicated that the disease could be checked to some extent, but only in one or two instances was it stopped entirely. From the time of its first appearance in July until the latter part of September the bitter-rot fungus was active. What became of the spores, where they remained over winter, and how they infected the fruit the following year was unknown, but the opinion was generally accepted that many of the spores survived in the mummified fruits which remained on the trees or on the ground throughout the cold season.

Up to within three years ago it was generally accepted that *Glœosporium fructigenum* Berk. was the cause of the bitter rot of apples. During the last two years, owing to the increased ravages of the disease, attention was directed toward the investigation of the life history of the bitter-rot fungus, with the result that a number of new facts of considerable importance have been determined. These facts have been discovered almost simultaneously by a number of observers, and their exact bearing on preventive measures has already been tested.

DISTRIBUTION OF THE BITTER-ROT FUNGUS.

GEOGRAPHICAL DISTRIBUTION.

The bitter-rot fungus, like other species of the form genus Glœosporium, has an almost world-wide distribution. In the United States it has been found in nearly all of the States east of and including Kansas, Oklahoma, and Texas. A careful search through the mycological literature available at the Missouri Botanical Garden has shown that under one name or another this fungus has been reported from Maine, New Hampshire, Vermont, Connecticut, New York, New Jersey, Delaware, Maryland, West Virginia, Virginia, North Carolina, South Carolina, Alabama, Mississippi, Kentucky, Ohio, Indiana, Illinois, Michigan, Wisconsin, Missouri, Arkansas, Kansas, Oklahoma, Indian Territory, and Texas. The States east of the Mississippi from which the fungus has not yet been reported are almost unexplored mycologically. It is extremely probable that it occurs in all States where the apple is being grown, even in the most northern latitudes. (See fig. 1.)

The bitter-rot fungus was first described in England from English

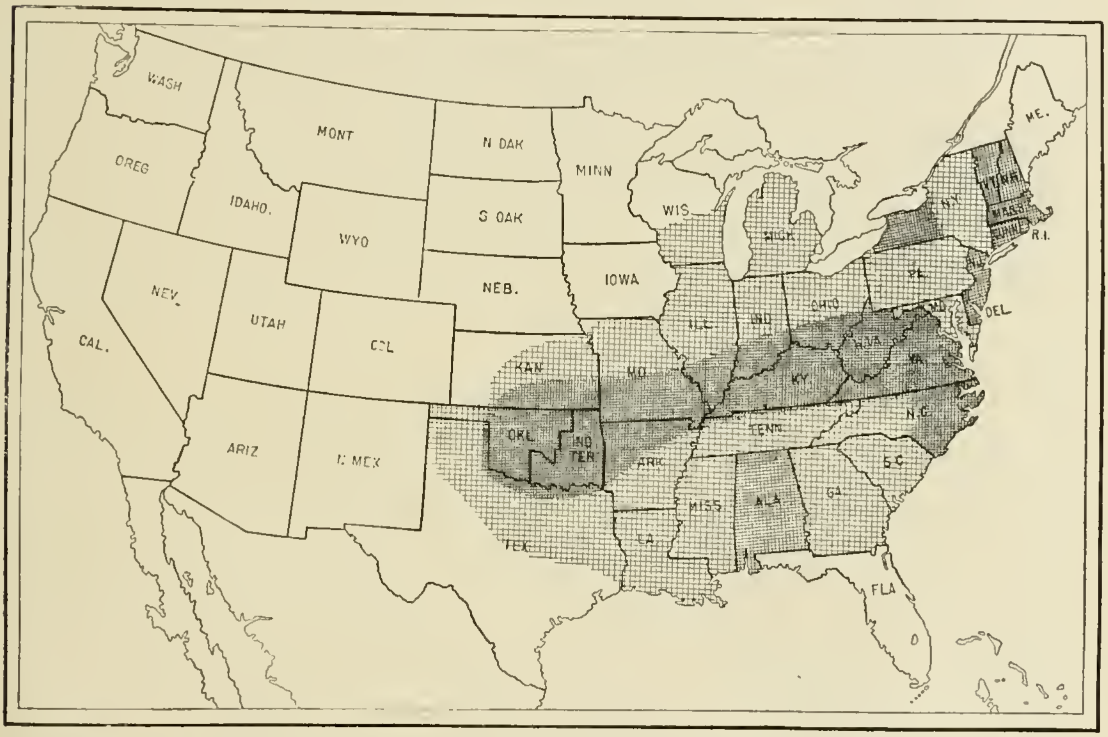

FIG. 1.—Map showing geographical distribution of the bitter-rot fungus in the United States. The shaded sections show where bitter rot occurs, the heavier shading indicating where the disease is most prevalent.

specimens. On one or another host the bitter-rot fungus has been found in all parts of the world. It is reported by Trail (1888), from Perth, Scotland; by Saccardo (1881), from Italy; by McAlpine (1895), from Queensland and New South Wales; by Cooke (1892), from Queensland; by Speschnew (1897), from Tiflis, in Transcaucasia; by Klein (see Frank, 1896), from Baden, Germany; also by Kirchner (1890), from various parts of Germany; by Nypel (1896), from Liege, Belgium; by Viala (1887), from France. It is probable that the fungus occurs to some extent in every country where the apple is grown, which is not surprising when one considers the manner in which apples are sent to all parts of the world and the excellent chances which spores of this fungus have for dissemination with the fruit.

OCCURRENCE ON VARIOUS HOSTS.

The first bitter-rot fungus was described in 1854 (Berkeley) as growing on grapes. Some years later the same writer described a fungus causing ripe rot of the apple. Berkeley in some later papers describes the ripe-rot fungus (under various names) as occurring on grapes, apples, peaches, and nectarines. In 1871 Berkeley, referring to a manuscript description of a fungus growing on grapes (*Glœosporium uvicola*), takes occasion to say that in his opinion it is the same as the fungus causing ripe rot of peaches and nectarines (*Glœosporium læticolor* Berk.). He states that "where grapes are grown in the same house with stone fruits the malady may spread upward," which may be taken to imply that he considered that the ripe-rot fungus of grapes may cause the disease of peaches and nectarines. He further emphasizes their probable identity by saying (p. 1163): "Both on grapes and stone fruits the spores of the fungus are very variable in size, so that no stress can be laid on mere measurement."

Von Thümen (1887) added the pear and the apricot to the list of hosts. Galloway, in 1890, demonstrated for the first time that the ripe-rot fungus of the grape, when transferred to the apple, caused the ripe rot or bitter rot of the apple, and vice versa. Miss Southworth, in 1891, confirmed these results.

Halsted, in 1892, published the results of a large number of experiments in which he had inoculated fruits with spores from different ripe-rotted fruits to determine whether the numerous forms of ripe rot or bitter rot were really due to the same fungus. His experiments seemed to prove that the same fungus caused the ripe rot of the apple, grape, peach, pear, pepper, tomato, and eggplant. The fungus was found to grow on bananas, quinces, lemons, and beans, in addition to the other hosts mentioned.

Chester (1893) corroborated Halsted's results so far as the tomato, grape, pepper, and apple were concerned. He came to the same conclusion as Halsted—i. e., that the fungus on the apple, grape, tomato, and pepper is biologically the same species. Alwood (1894) states that all pomaceous fruits are attacked by *Glœosporium fructigenum* Berk. During the last year Spaulding grew the fungus successfully on squash. (Pl. IV, fig. 6. See also Pl. IV, fig. 5, showing the fungus on the pear.)

From the evidence at hand it appears that this fungus can adapt itself to numerous hosts. It seems probable that all the forms are one and the same species, but it will be necessary to develop the perfect or ascus stage of many of them before any positive statement on this point can be made.

GENERAL DESCRIPTION OF THE BITTER ROT.

TIME OF APPEARANCE.

The bitter rot appears in an apple orchard at different times during the months of July and August, the time of its first appearance varying with the climatic conditions during any particular season. The first spots (Pl. IV, fig. 2) usually develop on the apple fruits when they are nearly full grown. From that time on until the fruit is entirely ripened the disease is likely to occur with increasing severity. In the Southern States bitter rot may destroy some fruit in the early part of July. In a number of cases apples only three-fourths of an inch in diameter were found affected with the disease. One of the writers collected apples affected with bitter rot in Vermont on October 20. The spots were small but well developed, and were present on a large number of individual fruits on one tree.

The factors which determine the time of appearance are probably (1) the age of the fruits; (2) the temperature and humidity of the air; (3) the presence of spore-distributing centers. The age of the fruit is a factor of considerable importance. As a rule, the green fruit is comparatively immune, which may be due in part to the large amount of malic acid present in the unripened fruit. It is possible to produce the disease on green fruits by artificial inoculation by allowing such fruits to lie on a shelf for several days after being picked. Different varieties of apples show a different susceptibility with respect to the time of attack. No hard and fast rule can, however, be laid down in respect to this matter, as the climatic conditions may hasten or retard attack.

Warm, sultry weather, particularly after a rain, forms the ideal condition for the development of the bitter rot. In cool, dry summers the bitter rot is usually present but sparingly. A short series of hot, wet days in August may bring about a sudden and very destructive attack. Nights with a heavy fall of dew alternating with hot days are usually followed by an extensive development of the disease. Numerous instances might be mentioned where the disease appeared in an orchard during the latter part of August, after a few hot days, destroying the whole crop in three days. A notable case of this kind occurred during the summer of 1900. Cold weather usually checks the disease and may stop it altogether.

The time of appearance of this disease is probably influenced also by the condition of ripeness of the spores in the cankers (as described later) and in the mummies. A cold spring may retard their development and consequently bring about a late attack on the fruit, or vice versa.

CHARACTER OF THE SPOTS.

The first signs of the bitter rot appear in the form of a very faint light-brown discoloration under the skin of the apple. The spots are exceedingly small at first, and as they grow larger they appear circular in outline. (Pl. IV, fig. 2.) The spots rapidly increase in size, becoming darker brown. When the spot is one-eighth of an inch in diameter the area appears distinctly sunken. The borders of these spots are usually very nearly circular and sharply defined. When about one-half an inch in diameter small black dots appear at more or less regular intervals beneath the epidermis in the sunken area. These increase in size and project as tiny raised points. At a later stage they break through the epidermis of the fruit and allow large numbers of spores to escape. (Pl. IV, figs 1 and 7.) These spores, when not washed from the fruit, form pink masses, sticky when moist. As the spore mass dries it cakes and adheres to the epidermis. On quiet, dry nights the spores are discharged in long tendril-like threads (Pl. VI, fig. 2), oozing out slowly from the mouths of the black bodies, which are the fruiting bodies of the bitter-rot fungus. These black bodies or pustules are often arranged in the form of a ring. (Pls. I and II.) As the rot progresses other rings of pustules appear outside of the first one, and at regular intervals six to eight, and sometimes more, well-defined rings may form in rapid succession. Each ring will have hundreds of pustules, each producing spores at the same time, so that some rings appear almost continuous. (Pls. I, II, and IV, figs. 1 and 7.) The formation of these rings depends on the rapidity with which the fungus grows. The most perfect rings of pustules are formed when the fungus grows most rapidly. (Pls. I and II.) Cold weather will be followed by a more or less irregular development of the pustules. (Pl. IV, fig. 3.) They then break through the epidermis at many points, as shown on Pl. IV, figs. 3 and 7. The arrangement of the fruiting bodies in rings is a common phenomenon among fungi. Where a single spore germinates in a medium where the food supply is abundant on all sides, the hyphæ generally grow in all directions with equal rapidity. When the period for the development of spores has arrived, the spores will be formed from hyphæ of the same age, i. e., at points equally distant from the original point of infection. The phenomenon of fairy rings is a notable instance among the higher fungi. Alternate periods of low and higher temperature may account for the intermittent development of fruiting bodies, and hence the formation of successive rings.

The pinkish appearance of diseased fruit is due to the spore masses which exude from the pustules. After a rainstorm the interior of the pustules looks sooty black and the mouths ragged, all the spores having been washed off.

The brown coloration of the spots on the apple fruit is an indication of the decayed condition of the tissues immediately under the spots, in which region the threads of the bitter-rot fungus are bringing about changes in the firm tissue of the fruit which make it appear decayed. The lateral progress of the disease, evidenced by the increasing diameter of the brown area, is accompanied by a corresponding progress of the disease into the fruit (figs. 2 and 3). The rotted mass, which is an inch in diameter at the surface, usually extends inward to the core of the fruit. The rotted mass shrinks somewhat in volume, hence the sunken character of the spot outside. There is usually a sharp dividing line between the rotted mass and the sound tissue. In this respect the bitter rot differs from the black rot of the apple.

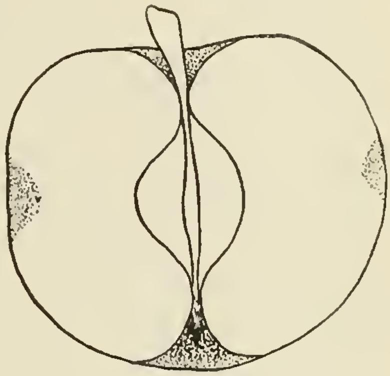
FIG. 2.—Diagram showing how the bitter-rot fungus decays an apple.

The size of the diseased areas on the fruit increases rapidly after an infection, and eventually the whole fruit may be affected. Where two or more separate infections take place the diseased masses fuse (Pl. I). The separate rings of fruiting bodies join and the two sets of hyphæ then grow on just as if there had been but one. The completely rotted fruit appears considerably shrunken, especially if there have been several centers of infection. The fruit hardly ever decays entirely, as do apples attacked by the black rot; as a rule there are small patches of healthy cells which hold out a long time. The affected fruit falls from the tree during all stages of the disease. (See Pl. III.) In this case, as in other instances of fruit diseases due to fungi, a hastening of the ripening process takes place. The diseased fruits are heavier than ripe fruits, and are readily shaken from the trees. There are probably other changes taking place in a diseased fruit which influence its condition and bring on premature fall, much as with fruits stung by various insects.

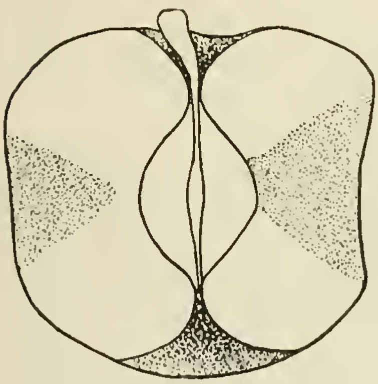
FIG. 3.—A later stage of bitter-rot decay.

CAUSE OF THE BITTER ROT.

The bitter rot of apples is due to a fungus, *Glœosporium fructigenum* Berk., which grows in the ripening tissues of the fruit, thereby inducing decay. The earliest accounts of this fungus deal largely with its systematic position, but it was recognized at an early date that the bitter rot or ripe rot of both apples and grapes was in some way connected with this fungus. A complete description of the fungus and its various stages is given in a succeeding chapter, and it will be necessary at this point to simply mention in brief the general appearance of the fungus in the orchard and the reasons for connecting this fungus with the bitter rot.

Reference has already been made to the appearance on diseased fruits of more or less regular rings of pustules. In these pustules small one-celled spores are formed, which exude from the pustules after they have broken through the epidermis. In the orchard these spores seem to be produced abundantly only when the air is heavy with moisture. Heavy dews and rain wash away the pink spore masses, leaving the ragged mouths of the pustules freely exposed. The appearance of the pustules and the discharge of the spore masses are the only evidences of fungus activity visible during the attack.

These pustules and spores are, however, always present in apples affected with the bitter rot, and no cases of this disease are known where these spores have not appeared at one stage or another. Moreover, inoculations of sound fruit with the spores of *Glœosporium fructigenum* Berk., made by many experimenters, have invariably produced the disease (Pl. II). There is, therefore, no doubt whatever that the bitter rot or ripe rot of apples and of some other fruits is caused by the bitter-rot fungus (*Glœosporium fructigenum* Berk.).

RATE OF DEVELOPMENT OF THE BITTER ROT.

The rate with which this disease develops depends largely upon conditions of temperature and moisture. During some summers it may take several weeks for the disease to develop to any extent after its first appearance. Then, again, it may start on a fruit during the night and in three to four days entirely destroy it. Apples inoculated with the bitter-rot fungus and kept in incubators at a temperature of 37° C. (98.6° F.) will show spots three-fourths of an inch in diameter, with numerous pustules, in forty-eight hours after inoculation. As has been stated above, the disease will develop in several days in epidemic form when heavy dews fall during the night, followed by hot, cloudy days. The condition of the apple fruit at the time of the attack influences to some extent the rate of development. Thus green fruits do not suffer as severely from the disease nor does the disease progress as rapidly as with fruits which are almost ripe. The disease progresses at different rates on different varieties of apples. Some are more easily affected than others. In general, it may be said that hot, muggy weather is most favorable for the rapid development of the bitter rot.

THE DISEASED APPLE.

An apple affected with the bitter rot or ripe rot is a most objectionable fruit. The name of the disease is derived from the peculiar bitter taste of the decayed tissues of the fruit which is noticed almost as soon as the fungus has begun its growth in the cells. One observer (Alwood, 1894) states that this bitter taste is not always present. The partially decayed fruit leaves a bitter taste in the mouth, resembling the after effect of quinine, yet not quite the same. The bitterness increases as the rot becomes more pronounced. The tissues of the apple are hard and firm when first affected; the cells look somewhat watery and are pale brown. As the rot advances the flesh of the apple softens and turns darker in color, until at an advanced stage the whole tissue is soft and mushy, very watery, and without any resemblance to the original healthy tissue. Attention should be called to the fact that in no case does the apple become as soft and mushy as it does when affected with most other fruit-rotting fungi, for instance, the black rot. The decay starts at the surface of the fruit and gradually extends inward toward the core, making a sort of cone-shaped mass of diseased tissue, as described above (figs. 2 and 3).

During the early stages of the disease there is a marked accumulation of starch around the affected spots, which calls to mind similar phenomena described by Halsted (1898) for various leaf-spot fungi. The cells of the apple tissue separate from one another as the disease progresses. The middle lamella of the cells is dissolved by the fungus hyphæ, but the cell walls themselves remain intact.

THE BITTER-ROT FUNGUS.

LIFE HISTORY ON APPLES.

The spores of the bitter-rot fungus germinate on the apple fruit when it is nearly ripe. In some cases the fungus has attacked apples when they were only three-fourths of an inch in diameter (Garman, 1893). which, however, may be regarded as exceptional. The hyphæ from germinating spores enter the apple and begin to grow in the layer immediately under the epidermis. Whether the young hyphæ can pierce the uninjured epidermis of the apple seems to be a somewhat disputed point. In making infections of apple fruits in the laboratory it was found that the greatest numbers of successful infections were obtained by puncturing the epidermis with a sterile needle and then spraying the spores on to the broken epidermis. Clinton (1902) states that the spores placed on unpunctured apples, "if successful," brought about the rot two or three days later than when placed on punctured fruits. It is probably true that the young hyphæ can enter through the unbroken skin, possibly through the stomates, but at the same time it is probable that a large percentage of the infections in an orchard start in fruits which have been wounded in some way, generally by insects. When one reflects that the number of spores which fall on a fruit is generally very large, it is strange that there should be only very few infections or sometimes only one infection. This point is one which will require additional careful study.

After the first hypha has entered the tissue below the epidermis it branches rapidly. The hyphæ grow in the intercellular spaces, absorbing the sugar and other products from the apple cells. (See Pl. V, fig. 3.) The affected cells turn brown and separate, and after a time they collapse. It is then that the presence of the fungus becomes noticeable on the outside in the form of the brown, sunken spots mentioned above (Pl. IV, figs. 1 and 2). The fungus hyphæ grow in all directions from the original point of infection with great regularity. As they extend outward the cell groups attacked become brown in turn and collapse more or less. This regular development gives the affected mass of cells the circular form visible on the outside.

Early in the season the brown areas are about one-half of an inch in diameter before there is any evidence of spore formation; later on, during the height of an epidemic, the spores begin to form when the affected areas are still very small. The spore-forming stage is evidenced by the appearance of numerous small raised points, which push up the epidermis in a brown spot at irregular intervals. These points are composed of masses of parallel hyphæ which grow outward from the cells just underlying the epidermis. These hyphæ are short and so arranged as to form a low cone, whose apex pushes against the epidermis as the hyphæ composing it grow in length. These hyphæ are at first colorless and then turn olive colored. Ultimately, either by pressure or because of the solvent action of an enzyme, the tip of this cone breaks through the epidermis. On the outside the tips of the cones appear as small dark specks. The unicellular spores are formed by abstriction from the ends of the hyphæ composing the cone, many spores being formed from each hypha. Great masses of these spores issue from the hole made in the epidermis and remain on the outside as bright pinkish, glistening masses, adhering to the tips of the cones. The latter are the pustules or sori. When the fungus is growing rapidly the pustules or sori may form when the spots are but one-fourth of an inch in diameter. The spore masses are sticky and adhere firmly to the mouth of the pustules. Sometimes, especially during nights when a heavy dew has fallen and there is an abundance of moisture in the air, the spores will be discharged forcibly in the form of tendril-like masses. (Pl. VI, fig. 2.)

As stated above, the sori appear in irregular groups early in the season. Later in the summer, when the fungus is growing rapidly, they break through the epidermis in groups, forming very regular rings (Pl. I). These rings are striking objects shortly after the discharge of the spores and form one of the most characteristic features of the disease. The spores disappear from the tip of the pustules after a time. Rain or dew may wash them away or insects rub them off. The empty sori remain behind and have a sooty, black appearance.

The time elapsing between spore germination on a fruit and the ripening of the first spore crop differs with the season from three or four days to a week. In hot days of August the cycle is completed with great rapidity. In one and the same spot on a fruit spores may be forming at the center, while a quarter of an inch farther out the pustules have not yet begun to develop.

The foregoing description of the growth of the fungus pertains to the development on apples still on the trees. Spores inoculated into apples after they have been picked will give rise to similar phenomena. The rate of growth of the fungus and the formation of spores will depend entirely on the temperature and moisture conditions under which the inoculated apple is kept.

The spores of *Glœosporium fructigenum* Berk. germinate on grapes when they are almost or quite ripe (Southworth, 1891). The bitter taste which follows the attack of this fungus on apples is absent in diseased grapes. Hence the more common designation of "ripe rot" for the same disease of the grape. On white grapes small reddish-brown spots appear, which spread and become darker as they grow older, until the spots have an almost purple center with a bright brown border. The pustules on the grape are at first white, then darker, until they are almost black. The spores are flesh-colored. The berry ultimately dries up, but does not turn black. Dark-colored grapes how no color changes when attacked.

THE CONIDIA

The spores of *Glœosporium fructigenum* Berk. produced in the sori, and commonly called conidia, are pinkish-colored en masse. This color varies from a light fresh pink to a darker reddish pink.[a] When highly magnified they have a very delicate light-green color. This color is quite distinct, and it seems strange that of many observers Alwood (1894) seems to be the only one to recognize this greenish color. Clinton (1902) states that the conidia are colorless, while Miss Southworth (1891) says that they are hyaline.

In size and form the conidia are extremely variable. The great variability in these respects has probably been responsible for the difficulties which many observers have labored under when it came to deciding which of the several fungi causing similar diseases of fruits

[a] One of the writers noted apples which had been inoculated in the laboratory and bore only cream-colored spore masses. The spores seemed to be perfectly normal in other ways.

properly belonged to this particular species. Alwood (1894) was able to produce in the same culture spherical, dumb-bell-shaped, oblong, ovoid, and cylindrical conidia. Although such extreme forms were not found by the present writers, they agree with Alwood and others that the form variation is certainly large. The general form of the conidia developed on fruits and in cultures may be characterized as oblong or cylindrical, sometimes slightly curved (Pl. V, fig. 1).

Extremes in sizes, gathered from all other writers, were from 6 to 40 μ in length and from 3.5 to 7 μ in width. The dimensions given by some may be mentioned. Alwood gives 10 to 12 $\mu \times 4$ to 6 μ. Saccardo's measurements, 20 to 30 $\mu \times 5$ to 6 μ, are probably of exceptionally large spores. The average size, as determined by the writers, is 12 to 16 $\mu \times 4$ to 6 μ.

Miss Southworth says of the conidia: "They are apt to be shorter and thicker on the apple [than in cultures], and in dry than in moist surroundings."

The spores can not and should not be taken as a criterion in determining whether any particular fungus is *Glœosporium fructigenum* Berk., since the spores of other species of Glœosporium closely resemble those of the bitter rot. The great variability in size and form of many fungi of a more or less saprophytic nature is coming to be more widely recognized, and the former method of lumping or separating many forms simply by spore characteristics is rapidly giving way to a clearer conception of the relationship based upon more constant characters.

The ripe conidia are filled with a finely granular protoplasm. Near the middle and usually a little to one side a clear hyaline area is generally visible (Pl. V, fig. 1). It is at this point that the septum forms during germination. Normally, the conidia are one-celled until they germinate. They resemble the ascospores of this same fungus, and the two can hardly be distinguished. As a rule the ascospores are slightly curved, while the conidia are straight.

GROWTH IN CULTURES—CONIDIAL AND ASCUS STAGES.

Freshly-formed conidia of the bitter-rot fungus germinate in three or four hours when put in water at room temperature. Just before germination a septum frequently forms at or near the middle of the spore, thus making a two-celled spore (Pl. V, fig. 2). A spore may produce one, two, or more rarely three, germ tubes (Pl. V, fig. 2). Where a wall forms, these two germ tubes start, one from each end of the spore. Short spores generally have but one tube. When the spores germinate in drops of water they become vacuolated after a few hours, and after five or six hours they become entirely empty. When germinated in bouillon or on agar, the protoplasm remains finely granular for some time and the cells rarely become entirely emptied.

The germ tubes grow in length with great rapidity, reaching a length three or four times that of the spore (Pl. V, fig. 2) in three-fourths of an hour. In a water medium the first hyphæ grow to considerable length before branching. In bouillon or agar they branch when two to three times as long as the spore. Septa form very early in the development of the mycelium (Pl. V, fig. 2).

Fusions between neighboring hyphæ are common both in the apple fruit and in cultures. The young hyphæ are colorless and are filled with a granular protoplasm. When growing in the tissues of the apple, the young hyphæ soon turn darker and ultimately become brown. When an abundant food supply is at hand the mycelium grows to large dimensions, and it may be several days before any fruiting bodies are formed. These are usually conidia formed by a process of abstriction at the end of short lateral hyphæ (Pl. V, fig. 7).

These conidia develop with great rapidity (Clinton, 1902), so rapidly that in twelve hours an agar plate will appear as if covered with a powdery mass. When growing under unfavorable conditions, so that the mycelium is starved, some of the hyphal tips will swell considerably, and a wall will cut off the swollen end (Pl. V, fig. 2). The walls of this swelling turn dark red-brown and thicken somewhat, forming what appears to be a spore (Pl. V, fig. 2). A bright translucent spot is usually present near the center. These brown bodies have various shapes and appear to be formed by most species of the genus Glœosporium. Miss Stoneman (1898) figures them for *G. fructigenum* and *G. naviculisporium*. Miss Southworth (1891) and Clinton (1902) obtained them in cultures of *Glœosporium fructigenum*. *Glœosporium cactorum* forms very fantastic bodies which bud and develop short tubes (Pl. V, fig. 4). Halsted (1892) published an extended account dealing with some of these secondary spores. Many attempts were made to cause the bodies formed by *Glœosporium fructigenum* to germinate, but so far without success. They probably represent a form of chlamydospore, which may have to undergo a resting period before developing.

The conidia formed freely from rapidly growing mycelium on agar resemble those from the pustules on apples in all respects. They germinate in a similar manner, and the mycelium which they give rise to may produce similar conidia, pustules, or perithecia, as the case may be, depending upon the age of the fungus, the food supply, etc. The fungus can be made to grow continuously, producing crops of conidia without the production of the other stages.

When kept growing on apple agar several crops of conidia usually form, as described above, and when the food supply has been partially exhausted the production of conidia gradually stops. The first lot of conidia have germinated by this time and have produced mycelia, so that a petri dish with a pure culture of the bitter-rot fungus is covered with a dense growth of mycelium after a period of from ten to fourteen days. At about the time when the conidia cease to be formed small black knots appear among the tangled mass of hyphæ, looking much like warts. Drops of a yellowish liquid frequently exude from these black bodies (Pl. VI, fig. 1) The latter increase in size and frequently form masses one-fourth of an inch in diameter. Cultures on apple agar will show good-sized masses of this kind in from twelve to eighteen days. These black masses contain the perithecia of the bitter-rot fungus.

The perithecia and asci were first described by Clinton (1902), who proved their connection with the bitter-rot fungus (*Glœosporium fructigenum* Berk.) by inoculating ascospores into apples and producing the bitter rot. The formation of perithecia was found by the writers to occur with great constancy under appropriate conditions. As a rule the perithecia form in older cultures only.

The black nodules in which the perithecia are embedded are hard masses of mycelium, which may be characterized as carbonaceous. They are very irregular in shape and vary in size from a small pin head to one-fourth of an inch in diameter. The perithecia, from one to many, are embedded in this carbonized mass. In apple-agar cultures the perithecia form when the black nodules are still very small. When there is but one perithecium in a nodule it is almost spherical; when there are several, they are somewhat flattened laterally, and sometimes very irregular in form. There is no beak. Clinton (1902) found the perithecia to be from 125 to 250 μ in length. These measurements agree fairly well with those found by the writers. The walls of the perithecia show marked reticulations about 6 to 14 μ in diameter. These are quite marked in the early stages, but become obscured as the perithecium matures.

The asci (Pl. V, fig. 6), which occur in considerable numbers in a perithecium, are oblong-clavate in form, 55 to 70 μ by 9 μ, often with a slight pedicel, and are comparatively thin walled. When mature they break open and disappear rapidly. They contain 8 ascospores, which are usually arranged in pairs, more rarely in oblique series. The spores resemble the conidia formed directly on the mycelium, so much so that they might easily be taken for conidia. They are perhaps curved a little more than the conidia, a character which can sometimes be used to separate the two, but not always. The ascospores and the conidia are about the same size, though the former are not as variable as the conidia, measuring 12 to 22 μ by 3.5 to 5 μ. Their great resemblance has probably led to the ascospores remaining undiscovered for so many years. The asci are short lived and after they have discharged the spores they vanish. When found in apples it is practically impossible to tell whether any particular spore is an ascospore or a conidium. The ascospores germinate much in the same manner as the conidia, and the description given for the germination of the conidia will hold for the ascospores.

Conidia were found in the bitter-rot canker during the summer of 1902, and in the latter part of 1902 perithecia and asci were found in the canker. (Science, **17**: 188, 1903.) The description of these will be given below in discussing the cankers.

The bitter-rot fungus grows readily on most culture media. It grows vigorously on apple agar, on sterilized apple wood or leaves, on sterile pine blocks, bean stems, etc. It is in many respects a true saprophyte. It is questionable whether it ought to be considered a parasite at all times when growing on the ripe fruit in the orchard, for at the time it attacks such fruit the latter is practically full grown and is no longer composed of cells or tissues which will react when stimulated. The fungus develops best at temperatures ranging from 33° to 38° C. (91.4° to 100.4° F.). Apples which were kept in incubators at 38° C. after infection showed decayed spots 1 inch in diameter in from one to three days. Cold checks growth materially, and at 2° C. or 35.6° F. (cold-storage temperature) no further growth takes place.

THE NAME OF THE BITTER-ROT FUNGUS.

About the middle of the last century a number of fungi were described by M. J. Berkeley as growing on various fruits and bringing about their decay. In 1854 he published the discovery of a fungus growing on grapes which caused ripe rot. He says of this:

> The surface of the spots is rough, with little, raised, orbicular, reddish bodies arranged in concentric circles and easily separating from the matrix, which is perforated for their protrusion. The outer surface of these bodies consists of delicate cells, with a distinct darker nucleus, and when this is removed a lobed hymenium is seen within, rough, with distinct sporophores, each of which is surmounted by an oblong spore, sometimes constricted in the center, and occasionally so much so as to become pyriform, and varying in size from $\frac{1}{1200}$ to $\frac{1}{150}$ inch. In age the perithecia fall away, leaving a little aperture, the border of which is often stained with black.

Berkeley named this fungus *Septoria rufo-maculans*, n. sp. He figures pycnidia and spores, and for reference the latter are reproduced herewith (fig. 4). In 1860 he changed the name to *Ascochyta rufo-maculans*. Von Thümen (1879) renamed this grape fungus *Glœosporium rufo-maculans* (Berk.) v. Th.

In 1856 Berkeley described a fruit-rotting fungus growing on apples, which he called *Glœosporium fructigenum*, n. sp. This is the first authentic description of a fungus causing bitter rot, or ripe rot, of apples. Berkeley says of this fungus:

> On examination each plant was found to consist of a branched inosculating mycelium, giving rise to simple or forked subfastigiate irregular threads, each tip of which was surmounted by an oblong, curved, or irregular spore about $\frac{1}{100}$ of an inch in length. There was not the slightest trace of an investing membrane or perithecium.

He refers to the description of a grape-rotting fungus two years before, and seems inclined to doubt the wisdom of considering the apple fungus a new species.

The spores (of the apple fungus) are more inclined to be curved, rather longer, and not so variable in size, and the want of a perithecium separated the two widely from each other. * * * At the same time these organisms are so different in different conditions that I would not affirm that the two productions are essentially different, and the more especially because in external appearance and habit they are so perfectly identical.

Berkeley's figures of this fungus are reproduced in figure 5.

In 1859 Berkeley published the name *Glœosporium lœticolor* n. sp., applying it to a fungus growing on peaches and nectarines. He evidently regarded this species as quite distinct from the apple and grape

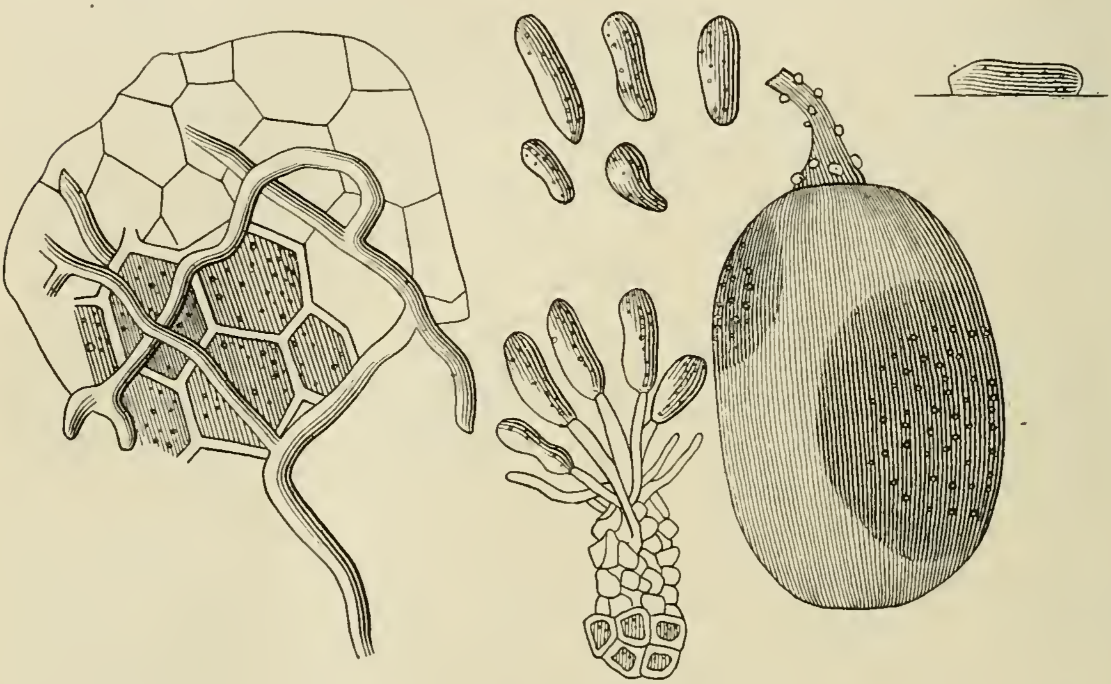

FIG. 4.—Berkeley's grape-rot fungus (*Septoria rufo-maculans* Berk.). [Drawn from the original figure.]

fungi, as he speaks of these in the following words (p. 676): "A plant of the same genus, destructive to apples, is figured and described in this journal (Gardeners' Chronicle, 1856, p. 245). * * * We may also refer to the very similar production on grapes."

In 1874 Berkeley and Curtis described a fungus growing on apples in South Carolina, calling it *Glœosporium versicolor* n. sp. They appeared anxious to emphasize the fact that this new fungus was not *Glœosporium fructigenum*, as they say: "It is very different in habit."

In the years following this last description the accounts dealing with the bitter-rot fungus on apples in the United States speak of it as *Glœosporium fructigenum* Berk., using the name given for the fungus on apples by Berkeley in 1856.

When Miss Southworth, in 1891, published an article on the bitter-rot fungus she reviewed the older accounts of fungi causing bitter rot or ripe rot of fruits, and decided to accept the name *Glœosporium fructigenum* Berk. for the fungus causing the bitter rot of apples. She gives her reason for so doing in the following words:

The strict law of priority might demand that we now make the specific name *rufomaculans*, but since the better-known *G. fructigenum* is also Berkeley's name it will remain so in this paper.

At this point it will be necessary to refer again to the results which Miss Southworth obtained by inoculating grapes with spores of the apple bitter-rot fungus (*Glœosporium fructigenum* Berk.) and apples with the grape ripe-rot fungus (*Glœosporium rufo-maculans* (Berk.) v. Th.). In both cases a bitter rot or a ripe rot of the respective fruits followed, which led Miss Southworth to regard the bitter-rot fungus and the ripe-rot fungus as one and the same species. The experiments of Halsted (1892) seemed to verify Miss Southworth's experiments

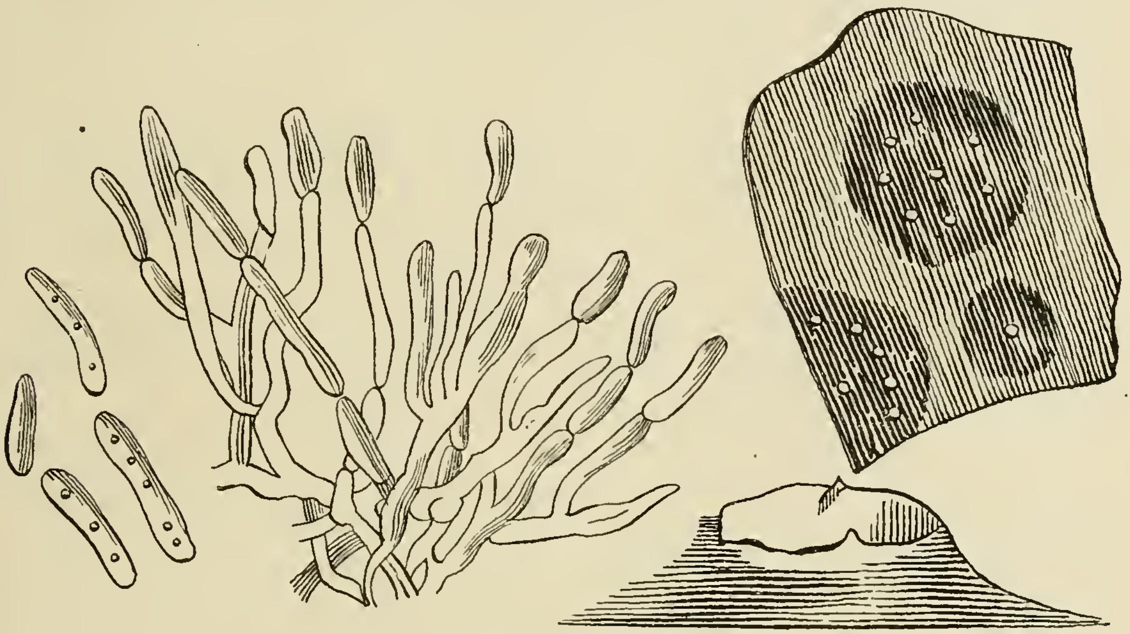

FIG. 5.—Berkeley's apple-rot fungus (*Glœosporium fructigenum* Berk.). [Drawn from the original figure.]

and to show that the same fungus caused the ripe rot not only of apples and grapes, but also of quinces, pears, peaches, nectarines, peppers, and other fruits.

Summing up the foregoing, it appears that several fungi causing fruit rots have been described under the impression that they were distinct species. More recent investigations have demonstrated that in all probability the same fungus has caused the various ripe rots of fruits. The different forms variously described as *Glœosporium fructigenum*, *Glœosporium rufo-maculans*, *Glœosporium versicolor*, and *Glœosporium læticolor* probably differ only in minor characters, such as in the size and form of the spores. The effects which they produce on different fruits vary as to color, size of spots, etc. These differences are readily intelligible in view of the better knowledge which we now have concerning the influence of different substrata on morphological characters of plants. This is particularly true of saprophytic fungi, which, like the ripe-rot or bitter-rot fungus, can grow on media of widely different chemical compositions. An abundant food supply may result in the production of very large spores, just as a meager supply may be followed by the formation of smaller spores.

The various fruits under consideration have a different structure and they differ chemically. It might, therefore, be expected that there would be slight differences in the structure of the fungus, and also in the external appearance of diseased fruits.

In cultures the various forms behave similarly. No such distinct physiological strains as were described for *Neocosmospora vasinfecta* by Erwin F. Smith (1899, p. 39) could be established. This is probably due to the more or less saprophytic nature of the fungus. *Glœosporium fructigenum* Berk. is not bound so strictly to the apple cell as the root-rot fungus is bound to the cowpea, the cotton, or the watermelon.

Assuming, then, that the four species mentioned above are one and the same, it becomes necessary to choose one of the four specific names. According to the generally accepted rules of nomenclature, the name under which the fungus was first known takes precedence, and in this case it is *Glœosporium rufo-maculans* (Berk.) v. Thümen.

This would have been the name of the bitter-rot fungus but for the discovery of the perfect or ascus stage. In 1902 Clinton placed the bitter-rot fungus in the genus *Gnomoniopsis* Stoneman.

In 1895 Miss Stoneman described a new genus *Gnomoniopsis* in which she placed (after obtaining in cultures the ascosporic stage) the following fungi, hitherto known only in the imperfect stages as members of the Melanconiaceæ: *Glœosporium cingulata* Atk., *Glœosporium piperatum* E. & E., *Colletotrichum cinctum* Berk. & Curt., and *Colletotrichum rubicolum* E. & E. Clinton included the bitter-rot fungus *Glœosporium fructigenum* Berk. in this group and named it accordingly *Gnomoniopsis fructigenum* (Berk.) Clinton. It is under this name that the fungus now stands.

In establishing the genus Gnomoniopsis Miss Stoneman, however, overlooked the fact that six years prior to her publication Berlese (1892) used the name *Gnomoniopsis* for a group of fungi very different from the perfect form of the *Glœosporium* which she described. Clinton, in accepting Miss Stoneman's name, likewise overlooked the name published by Berlese. The latter raised the subgenus *Gnomoniopsis* of the genus *Gnomonia* as used by Winter (1887) to generic rank, making the species *Gnomonia chamaemori* (Fries) the type, and including in the new genus the former *Gnomonia misella* as a variety of *Gnomoniopsis chamaemori* (Fries). Lindau (1902) accepts Miss Stoneman's genus *Gnomoniopsis*. The generic use of *Gnomoniopsis* by Berlese in 1892 clearly invalidates Miss Stoneman's name, and it becomes necessary to rename the genus. The name *Glomerella* is suggested by the writers. The bitter-rot fungus would accordingly become *Glomerella rufomaculans* (Berk.) Spaulding & von Schrenk, with the following synonymy:

Glomerella rufomaculans (Berk.) Spaulding & von Schrenk.[a]
Septoria rufo-maculans, Berk. (1854, Gard. Chronicle, p. 676).
Ascochyta rufo-maculans, Berk. (1860, Outlines of British Fungology, p. 320).
Glœosporium rufo-maculans, (Berk.) v. Thümen (1879, Fungi Pomicoli, p. 59).
Glœosporium fructigenum, Berk. (1856, Gard. Chronicle, p. 245).
Glœosporium laeticolor, Berk. (1859, Gard. Chronicle, p. 604).
Glœosporium versicolor, Berk. and Curt. (1874, Grevillea 3: 13).
Gnomoniopsis fructigena, (Berk.) Clinton (1902, Bull. Ill. Agr. Exp. Sta.).

The new genus *Glomerella* stands practically for the genus *Gnomoniopsis* Stoneman, and accordingly includes all the species, four in number, which were placed by her in the genus *Gnomoniopsis*, i. e., they become *Glomerella cingulata* (Atk.) Spaulding & von Schrenk, *Glomerella piperata* (E. & E.) Spaulding & von Schrenk, *Glomerella cincta* (Berk. and Curt.) Spaulding & von Schrenk, *Glomerella rubicolor* (E. & E.) Spaulding & von Schrenk.

Glomerella rufomaculans may be described, using the description given by Clinton (1902), which agrees with the finding of the writers so well that it fully covers all points.

Glomerella n. n. (*Gnomoniopsis* Stoneman, not Berlese). Perithecia membranaceous, dark brown, spherical to flask-shaped, often rostrate, sometimes evidently hairy, cæspitose or more or less compound and immersed in a stroma with which they often form an evident hard cushion; asci oblong to clavate, often fugacious, aparaphysate; ascospores hyaline, apparently eight, distichous, oblong, usually slightly curved, unicellular. Permanent stage of Glœsporium-like fungi.

Glomerella rufomaculans (Berk.) Spaulding & von Schrenk. Permanent stage developing on decayed pomaceous fruits; forming stromatic cushions (often concealed by dark olive mycelial felt), which contain immersed and more or less compounded, subspherical perithecia; asci subclavate, often slightly pedicellate, fugacious 55–70 μ in length, ascospores alantoid, with evident central hyaline area chiefly 12–22 μ by 3.5–5 μ. Glœsporium stage causing rotting of pomaceous fruits; sori small, developing more or less in concentric circles, usually soon rupturing and oozing out spores in small pinkish masses; spores greenish,[b] chiefly oblong, unicellular, with evident hyaline areas when fresh, 10–28 μ by 3.5–7 μ, but chiefly 12–16 μ by 4–5 μ.

To this must be added: The fungus forms cankers on apple limbs, bearing both conidia and perithecia.

THE CANKER STAGE.

DISCOVERY OF THE CANKER.

The sudden appearance of the bitter-rot fungus late in the summer and its equally sudden disappearance in the early winter have long excited conjecture as to where the spores which affected the first apples every year came from. Diseased apples of a previous year hanging

[a] The writers have dropped the hyphen from rufo-maculans in order to simplify the name, as was done by Cooke (1885).

[b] Changed by the writers. The original says "hyaline."

in mummified condition on the trees, or lying on the ground under the trees, probably served as infection centers in many instances; but in many cases, although all mummies and diseased apples were carefully removed during the winter, the disease reappeared in the orchard. Another feature explained with difficulty until recently was the fact that even with many specimens of bitter-rotted apples of the previous season lying on the ground under the trees, the disease first manifested itself in the tops of the trees and very rarely on the branches nearest the ground. In other words, it was difficult to understand how the spores of the bitter-rot fungus got on the fruits in the tree tops from the mummies on the ground without first infecting those on the lower branches. It had been noted repeatedly that the disease frequently made its first appearance on the apple tree in a cone-shaped area, with the apex of the cone near the top of the tree. It was this observation oft repeated which led to the discovery during the past summer of what is probably the winter stage of the bitter-rot fungus.

On July 10, 1902,[a] Mr. R. H. Simpson discovered peculiar depressions on many branches of apple trees in his orchard at Parkersburg, Ill. Mr. Simpson was at that time employed as an agent of the Department of Agriculture to conduct spraying experiments looking toward the control of the bitter rot of apples by spraying with fungicides. Mr. Simpson had been hunting for the source of the first infection, and early in July he noted the peculiar cone-shaped distribution of the fruit which showed the first signs of the bitter rot. On many trees the grouping of the infected fruit in the cone shape was so marked that it seemed probable that the disease had started near the apex of the cone and had spread downward and outward. In nearly every instance Mr. Simpson found blackened depressions of a characteristic appearance on one or more branches at or near the apex of the cone of infected fruit. These black depressions in the apple limbs occurred so constantly associated with early bitter-rot infection that Mr. Simpson proceeded at once to cut out all blackened areas which he could detect. The blackened sunken areas in the apple limbs have the appearance of "cankers," as this term is generally understood, and they have been called cankers since their first discovery. Mr. Simpson was able to locate the canker in more than 95 per cent of the cases by following up the cone of infected fruit to the apex.

On the day following Mr. Simpson's discovery at Parkersburg, Professors Burrill and Blair, of the University of Illinois, visited the orchard at Parkersburg and learned of Mr. Simpson's find. Believing that the causal relation between the cankers and the bitter rot was thereby established, they published a preliminary note in a circular of the Agricultural Experiment Station of Illinois, in which they

[a] The discovery of the apple cankers was made July 10, 1902, in the afternoon, as indicated by a telegram from Mr. Simpson to the writers on the same day, not July 11, as stated in Circular No. 58 of the Illinois Agricultural Experiment Station, July, 1902.

recommended cutting out all cankers in apple orchards. This preliminary circular was followed by a bulletin on the same subject, giving illustrations of the cankers and results of experiments, showing that bitter-rot spores occurred in the canker and that apples could be infected from cankers.

Investigations as to the relations of the cankers and the bitter rot were begun by the writers two days after Mr. Simpson's discovery. These have been continued up to the present time and will be carried on further.

DESCRIPTION OF THE CANKER STAGE.

The cankers found on apple trees in Illinois appear as blackened depressions on apple limbs of various sizes, from last year's fruit spurs to limbs 3 to 4 inches in diameter. Thus far the cankers have not been found on the main trunk. On these limbs rounded or oblong sooty-black sunken spots occur from one to several inches long, which have more or less ragged edges. (See Pls. VII and VIII.)

The entire bark is killed for a considerable distance back (Pls. VII and VIII), and the dead bark appears cracked and fissured and in some instances broken away. In many cankers regular transverse cracks, caused by the drying out of the bark, are very marked. As the bark dries out it adheres very firmly to the underlying wood. As a result of the decrease in volume of the affected bark and cambium, a marked flattening and final depression take place on the affected limb. Around the dead areas a healing callous layer usually forms (Pl. VII, fig. 1; Pl. IX, figs. 1 and 4). This starts at the edges of the dead areas and pushes toward the center, frequently lifting the dead bark at the edges. The appearance of this callous layer makes the cankered spots look more and more sunken. It will be noted that most of the cankered spots show the presence, near the center, of a small branch or of a branch stub. There may be some relationship between the formation of the cankered spot and a diseased fruit borne on such a small branch in a previous year. That is, however, a mere conjecture.

On cross sections of cankers one frequently finds that at its very center the wood has been dead for two years. (See Pl. VIII, fig. 1.) The small hole in the wood, two rings in, shows where the small branch broke away. This dying and breaking away of the small branch would point to the fact just mentioned, that the canker may sometimes start in the branch.

The wood of the branch immediately below a cankered spot is discolored for a considerable distance toward the center. (See Pl. VIII, fig. 1.) The discoloration is brown and resembles that found in many hardwood trees in the region below a wound. The wood cells and medullary rays in the discolored region are filled with a light brown mass, readily soluble in alkalis, which leads one to class it as one of the humus compounds. It is probably one of the decomposition products which forms when the bark and cambium are killed and which infiltrates the wood. One finds numerous fungous hyphæ in the medullary ray cells and the larger vessels, but at this stage it is not possible to say whether these are hyphæ of the bitter-rot fungus. Further studies in this direction are being made.

The formation of the cankered spot probably starts at some small wound (or branch, as stated above). The fungus begins to grow in the living bark and kills the bark and the cambium. As a result no new wood is formed at the point where the cambium is killed (see Pl. VIII, fig. 1), and a small depression forms as the wood at the edges of the dead cambium increases in thickness. As the fungus grows out from the original point of infection, more and more bark and cambium are killed, until at the end of the growing season a large spot on the limb is dead.

Since there is always a small series of wood cells formed at the beginning of the year during which the attack takes place, the fungus probably starts to grow in the bark early in June. (See fig. 6.)

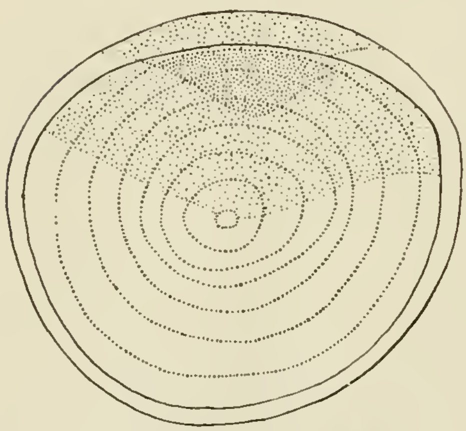

FIG. 6.—Diagrammatic cross section of apple canker.

The majority of the cankers found during the last summer probably were started two years ago. During the first year the fungus made very little headway. A very small central area was killed, generally around and including a small branch. The following year the larger part of the canker was formed. Whether the cankers will continue to increase in size is as yet undetermined, but it does not seem probable, for if such were the case cankers three or more years old ought to have been secured in the orchards where the bitter rot has been common for many years.

RELATION OF THE CANKERS TO THE BITTER ROT.

The discovery of the cankers was brought about directly by tracing groups of diseased apples to these sunken areas on apple limbs. The numerous observations made by Mr. Simpson and by those who followed him seemed to prove beyond question that the cankers were in some way responsible for the infection of the apples. Instances were frequent where two or more apples hung just below a canker. These were generally badly diseased, while all other apples in their immediate vicinity were perfectly healthy.

Although it seemed extremely probable from Mr. Simpson's observations, confirmed and extended by the writers, in his orchard and in other orchards, that a causal relation existed between the canker on apple limbs and the bitter rot, it was by no means positively proved that the bitter-rot fungus (*Glomerella rufomaculans* (Berk.) Spaulding & von Schrenk) produced the cankers on apple limbs. Experiments were accordingly started to determine whether any such relation existed. Examination of the cankers showed the presence of unicellular spores resembling the spores of *Glomerella rufomaculans* Berk. In most cases there also occurred numerous unicellular brown spores of a fungus which was probably *Sphæropsis malorum* Peck. There were spores present now and then of *Tricothecium roseum* and a species of Alternaria, but the unicellular colorless spores (*Glomerella rufomaculans*) and the unicellular brown spores (*Sphæropsis malorum*) were quite constantly present. The mere presence of spores of any one fungus, even when constantly associated with a canker, is no proof that the fungus producing these spores causes the cankers. It is strong presumptive evidence, but no more. That the colorless one-celled spores were spores of *Glomerella rufomaculans* was proved after a few days by inoculating some of these spores obtained from a canker into healthy apples. These showed unmistakable signs of the bitter rot in a few days. (See Pl. II.) This experiment was repeated many times, using control fruits with every culture. In every case the bitter rot appeared in inoculated fruits, while the check fruits remained sound. Fearing that the spores which caused the disease in these cases might have simply rested in the bark of the cankers, numerous cultures on apple agar were made from pustules in the bark of cankers, and from these pure cultures of the bitter-rot fungus were obtained.

Spores from such pure cultures were inoculated into sound apples, using control fruits, and these also produced the disease (Pl. VI, figs. 3 and 4). These cultures, repeated for several months and under different conditions, left little doubt that the cankers on apple limbs contained spores of the bitter-rot fungus (*Glomerella rufomaculans* Berk.).

A number of tests were made to determine whether the spores could be washed from a canker onto apples by water falling on the cankers. The first test of this kind was made by Mr. Simpson. To insure rapid action on the part of the fungus, he punctured an apple, and then allowed water to run from a canker on the fruit. After several days this apple showed unmistakable signs of the disease.

It now became a matter of considerable importance to determine what connection, if any, existed between the bitter-rot fungus and the cankers. It was very possible that the cankers served merely as lodging places for the bitter-rot fungus or its spores. The presence of numerous spores of what was believed to be *Sphæropsis malorum* suggested that this fungus, which is known to form cankers on apple limbs (Paddock, 1899 and 1900) resembling those in the Illinois orchards, might be the canker-forming fungus. This supposition was strengthened by the fact that many of the Illinois cankers had the sooty black appearance characteristic of the black-rot apple cankers.

To determine whether the bitter-rot fungus (*Glomerella rufomaculans*) could form cankers, a number of trees in the Missouri Botanical Garden were selected. Small longitudinal slits were cut into the bark, reaching the cambium layer, two slits on every branch. Into the upper slit spores from pure cultures of *Glomerella rufomaculans* (made from diseased apples and from cankers) were introduced. The second slit, from 3 to 5 inches below the first, was used as a control. A large number of control slits were used, as it was possible for spores flying about in the air to enter the infected slits and thereby vitiate the results. It may be said at this point that in no case did any of the control slits show any signs of canker formation. A number of inoculations were made, using pure cultures of *Glomerella rufomaculans* obtained from apple cankers in Illinois and from diseased apples. Inoculations were likewise made with ascospores obtained in apple agar cultures. The first infection of apple limbs was made July 16, 1902.

The inoculations were made by inserting a needle with spores into the freshly made slit, or by spraying water into the slit and then placing some spores in the drop of water. Some of the slits were covered with grafting wax or with cloth waxed with a cocoa-butter mixture, as it was thought that the uncovered slits might be infected by bitter-rot spores from the air. The results showed that this precaution was useless, as none of the uncovered control slits showed any signs of being infected.

Several weeks elapsed before there was any evidence of development on the limbs. In both the inoculated slits and the control slits the bark dried somewhat along the edges of the slit, making a gaping wound. After some two weeks a distinct callous layer had formed under the edges of the bark of the control slits. The two callous layers joined after six to eight weeks and occluded the wound. In the slits where bitter-rot spores had been inserted the callous formation was less marked. The exposed wood turned dark, almost black, and the exposed edges of the bark turned back. The living bark then began to dry out gradually and became depressed (Pl. IX. fig. 3), and after about two months a decided sharply defined depressed area had formed, with the slit in the center. Shortly thereafter small black pustules broke through the dried bark in a number of instances (Pl. IX, figs. 2, 4, 5, and 6). By that time the infected points showed all the characteristics of small cankers.

On examination the black pustules were found to contain masses of spores resembling those of the bitter-rot fungus (*Glomerella rufo-*

maculans). At this time there were no other spores in the canker, such as the brown *Sphæropsis* spores. Inoculations were immediately made with the spores which had formed in the pustules of the cankers produced on the apple limbs, using healthy apples.

Several days thereafter these apples showed all signs of the bitter rot, and after three days quantities of bitter-rot conidia were produced in the characteristic manner already described. These results proved that the fungus growing in these cankers was actually *Glomerella rufomaculans*.[a] Some of the more striking cases of artificial cankers are reproduced on Plate IX. Figures 2, 3, and 4 show artificial cankers, with control cuts above. Figure 5 shows one of the cankers (fig. 4) somewhat enlarged, with numerous black pustules.

These results showed beyond question that the bitter-rot fungus *actually produces the cankers on apple limbs*, and is not merely present in cankers which are produced by some other fungus. There was no question as to the purity of the cultures used for inoculating the apple limbs, and as there was no growth in any of the control cuts there is no reason for doubting that the fungus inoculated into the cuts on apple limbs grew in the bark and formed the pustules containing spores, which in turn produced the bitter rot in apples.

A further proof that the fungus produced the cankers was brought forward by the discovery (by Spaulding, December 24, 1902[b]) of perithecia and asci, with ascospores (Pl. V, fig. 7) of *Glomerella rufomaculans*, in one of the cankers artificially produced on apple limbs by inoculating conidia of *Glœosporium fructigenum* Berk. into apple limbs. Spaulding found that many of the spores in the artificial cankers were curved very much like the ascospores of *Glomerella rufomaculans* obtained in cultures on apple agar. The conidia and ascospores of this fungus look very much alike—so much so that it is not easy to separate them with any degree of accuracy. The only difference which is at all evident is that the conidia are usually straight, while the ascospores are slightly curved. (Pl. V, fig. 6.) Sections of the canker made by Spaulding showed the presence of perithecia (Pl. V, figs. 5 and 7), most of which were empty. Several were found, however, with asci and ascospores. (Pl. V, fig. 7.) It seems that the asci in the cankers have as little permanence as do those found in cultures. Clinton refers to the comparatively evanescent character of the asci which he found in the cultures, and we can testify to the same statement. So far as could be determined, the perithecia and asci in the cankers were identical with those of *Glomerella rufomaculans* formed in cultures. Up to this writing no perithecia or asci have been reported from the cankers on apple limbs in the orchard.

[a] A preliminary note announcing the proof of a causal relation between the bitter-rot fungus (*Glœosporium fructigenum* Berk.) and the apple cankers was published in Science, 16: 699, 1902.

[b] See Science, 17: 188, 1903.

Summing up the evidence now at hand as to the causal relationship between the bitter-rot fungus (*Glomerella rufomaculans*) and the apple cankers found in certain apple orchards in Illinois and other States, we find (1) that conidial spores of this fungus which will produce the bitter rot in apples occur with great regularity in the cankers; (2) that such conidial spores taken either directly from diseased apples or from pure cultures made from cankers or diseased apples, when inoculated into the living bark of growing apple-tree branches, will produce apple cankers resembling those found in the orchards; (3) that conidial spores and asci and ascospores are contained in such artificially produced cankers, which, when inoculated into apples, produce the bitter rot.

Taken together, these facts seem to prove beyond question that the bitter-rot fungus can grow in apple branches, that by so doing it forms cankers, and that after a time spores are formed in such cankers, which produce the bitter rot in apples.

Although this fact seems established at present, the writers are by no means convinced that sufficient proof is yet at hand which would warrant the statement that *all* of the cankers found in the Illinois orchards were formed by the bitter-rot fungus. The resemblance between the canker formed by the black-rot fungus *Sphæropsis malorum* Peck on apple limbs in New York (Paddock, 1899 and 1900) and the cankers formed in Illinois suggested at first that the latter were formed by the black-rot fungus. This supposition was strengthened by the almost constant presence of spores of *Sphæropsis malorum* Peck in the Illinois cankers. The black-rot fungus is known to form cankers on apple limbs with great readiness, and the black rot is a common enemy of the apple in Illinois and adjacent States. The writers are therefore of the opinion that it is not at all improbable that the Illinois cankers are formed in part by *Sphæropsis malorum* Peck. The bitter-rot fungus may get into the young Sphæropsis cankers and both fungi may grow side by side. Considerable additional work will have to be done with these cankers before their exact identity will have been established.

SPREAD OF THE BITTER ROT.

Nearly all those who have studied the bitter rot agree that the fungus is very erratic in its time of appearance. The disease may be prevalent year after year in a particular part of an orchard without occurring in other places in the same orchard or in other orchards in the immediate locality. It has been repeatedly noted that the rot seemed to start in one tree or a group of trees close together and that it spread from the center to adjoining trees.

Observation showed that the rot was more likely to appear on trees which had once had the disease than on trees previously free from it.

One apple grower carefully marked the trees which were affected with bitter rot in 1900. When the rot first appeared in his orchard in 1902 (there was hardly any rot in 1901) he went over the orchard and found that every tree marked in 1900 had bitter rot, and not only that, but that the rot was at first confined to these trees.

Another observation frequently recorded is that the disease often starts on a few trees and, starting from this center, it gradually spreads year after year and finally affects the entire orchard. Mr. J. W. Beach, of Batavia, Ark., stated a typical case:

> I came to this country in 1884, and that season there were four trees in my old orchard affected. * * * For the last three years the disease has steadily increased, so that this year (1887) my old orchard of seventy-five trees will not yield 25 bushels of sound apples.

This apparently erratic behavior of the bitter rot can be explained in part since the discovery of the canker stage of the fungus. After its introduction into an orchard or on one tree the fungus attacks one or more branches, probably early in the summer, and produces a canker. The next year the spores from this canker will be washed down on the ripening fruit by a rain. The water is sprayed from the branch on which the canker is situated to the lower branches in the form of a cone, and one or more spores will probably fall on every apple within such a cone.

The presence of the winter stage of the fungus will explain why the rot is apt to recur on the trees affected the year before with the bitter rot, and also why the disease should first appear on such trees. The cankers produce spores early in the season, and from the trees which have cankers the disease spreads to neighboring trees.

The bitter rot is apt to appear in virulent form only once in two or three years. During the intervening periods there may be little or no rot in any one region. This may possibly be caused by weather conditions generally unfavorable to the fungus, as was the case in the summer of 1901, but it may also be due to conditions unfavorable to the growth of the fungus in the cankers.

The exact conditions which favor the development of the bitter-rot fungus on the branches are not known as yet, but it is conceivable that these might be such as would retard its growth in the canker to such an extent that few or no spores would be found during one year.

That the spores of the bitter-rot fungus are spread to the fruit from the cankers in the tree now seems proved beyond doubt. The dissemination of spores from the cankers probably begins early in summer and continues until the apples are fully grown.

Another source of infection is found in the dried mummies hanging on the trees and lying on the ground under the trees. The diseased apples of one season either fall to the ground (which most of them do) or they remain on the trees, where they dry and shrivel up. When examined in the spring many of these mummified fruits are found to contain spores of the bitter-rot fungus in quantity. Inoculations made by us with such spores have shown them to be fully capable of remaining alive over winter and of producing the disease in July and August of the following year.

It was formerly supposed that the fungus passed the winter in the mummies, but as most of these were on the ground it was difficult to understand how the apples high up in the trees became infected. It now seems probable that the mummies play a comparatively small part in serving as distributing points for spores from year to year.

After the fungus becomes started on a number of fruits it spreads to neighboring apples and trees with great rapidity. The sticky nature of the spore masses precludes any theory of wind distribution. The spores are never dustlike, so that they could be blown about, but are generally stuck together, forming a sticky, paste-like mass. Rain and dew play an important part in distributing the spores.

Numerous small insects which frequent apple trees in the late summer, such as members of the genus Drosophila, probably carry the bitter-rot spores from one tree to another. Clinton (1902) proved that this was actually the case by placing some of these flies on sound apples and thereby producing the disease.

REMEDIAL MEASURES.

Although the bitter rot has been so destructive to apple crops for thirty years or more, little if any headway had been made until recently toward combating it successfully. The disease may still be regarded as one of the most difficult ones to control, although it now seems probable that greater success ought to attend preventive measures. These may now be placed under these heads:

1. Removal of diseased fruits and mummies.
2. Removal of limb cankers.
3. Spraying with fungicides.

REMOVAL OF DISEASED FRUITS AND MUMMIES.

Apples affected with bitter rot generally fall from the trees during the later stages of the disease. In many cases the spores in these rotted apples will live through the winter, and may be carried to sound fruits the following season. Such apples as do not fall dry up and hang on the trees all winter in a mummified condition. The next year the spores formed in these mummies may infect sound fruits. All diseased fruits on the ground should be carefully collected as soon as they fall; they should be removed from the orchard and destroyed either by drying and subsequent burning or by burying them in a deep trench, which is carefully covered with soil afterwards. Under no circumstances should the rotted fruits be allowed to remain lying on the ground under the trees through the winter.

Dried apples on the trees should be picked and burned as soon after the fall of the leaves as possible.

Where the bitter rot appears in an orchard at isolated points it will oftentimes pay to watch the trees where the trouble first shows itself and to pick every fruit showing the slightest sign of disease. In that way the chance of having the disease spread to adjoining trees will be materially lessened.

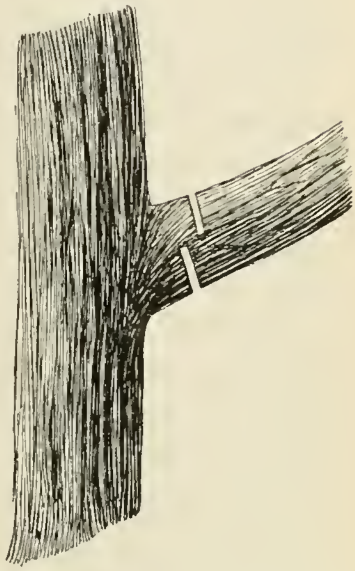

Fig. 7.—How to cut off a large limb.

REMOVAL OF LIMB CANKERS.

It seems well established now that one of the principal sources of infection of the ripening apples is to be found in the cankers on apple limbs. These cankers should accordingly be removed and burned wherever they are found, no matter where the affected limb may be. It is often a difficult matter to find these cankers on large trees, and a good deal of patience is necessary to locate them. In cutting out the cankers the whole limb should be sawed off some distance below the cankers. Where the branch is a large one the diseased portion may be cut out without cutting off the entire limb. The best time for cutting out the cankers is during the late fall and during the winter. The cankers can be located most readily when there are no leaves on the trees. In cutting off limbs which have cankers on them, the same rules which hold for pruning branches should be observed. Small branches may be cut off with a saw at one cut. Two cuts should be made for larger branches, the first one on the under side, the second on the upper side, so as to prevent tearing off large areas of bark. (See figs. 7 and 8.)

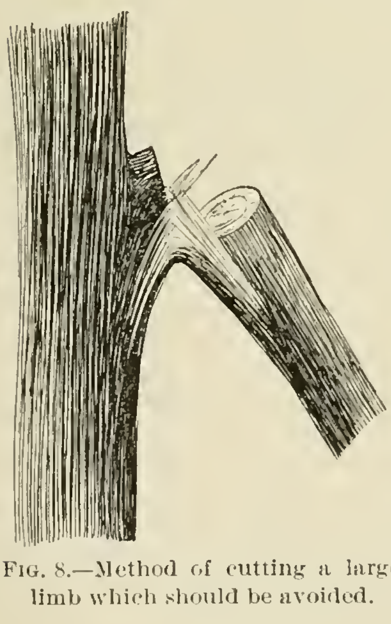

Fig. 8.—Method of cutting a large limb which should be avoided.

All cut surfaces should be carefully trimmed, and after that they should be coated with some antiseptic substance, such as white lead paint or ordinary coal tar. The coal tar should be applied with a brush, and if too thick, it may be warmed. It is believed that by carefully removing and destroying all cankers the damage from bitter-rot infection will be very materially lessened.

SPRAYING WITH FUNGICIDES.

Prior to 1887, at a time when the bitter rot had already a wide distribution, no attempts seem to have been made to control the disease. Galloway said (1887): "With our present limited knowledge of its habits, it is impossible to suggest means for combating it." Two years later the same writer suggested spraying the fruit trees with sulphuret of potassium when the apples were about half grown, and repeating the operation every two or three weeks throughout the summer. In a brief note during the same year (1889) Galloway referred to some experiments made by Beach in 1888 with sulphuret of potassium, in which he stated that "Mr. Beach has full confidence in the remedy." Galloway (1889) reported some tests made with potassium sulphide and ammoniacal copper carbonate by Curtiss. A good many apples were saved by the spraying, little difference being noted in the results accomplished by the use of the two solutions mentioned.

Chester (1890) sprayed with potassium sulphide, liver of sulphur, and ammonium copper carbonate without decided success.

Garman (1894) published an account of a series of experiments to control diseases of apples with Bordeaux mixture. In his general summary he states:

> The proportion of rotting to nonrotting apples was in every case lessened by spraying, and we are in a position to say, as a result of these experiments, that spraying with Bordeaux mixture will save from rotting from $7\frac{4}{5}$ per cent to $31\frac{1}{6}$ per cent of the whole number of apples. * * * The spraying increased the yield of usable apples from a little less than twofold to nearly sevenfold.

From the beginning of the nineties to the present time a number of experiments in spraying have been made by several persons, notably Alwood (1892, 1894), Stinson (1892, 1894, 1896, 1901, and 1902), Whitten (1895), Clinton (1902), Staubenrauch (1902), Burrill and Blair (1902, a and b).

Without going into details, it may be said that the results reached were favorable in some cases, but not so successful in others. Alwood (1894) states:

> Our results with Bordeaux mixture and ammonia copper carbonate, as recommended in bulletins mentioned above, are very satisfactory.

Whitten (1895) says:

> Bitter rot began first on unsprayed trees and developed more extensively than on sprayed trees. Bitter rot was less on trees sprayed with the 6-pound solution (of Bordeaux mixture) than on those sprayed with the weaker solutions.

Stinson (1896) says:

> There was much less bitter rot on the sprayed fruit than on the unsprayed. From the results obtained it was concluded that the injury can be partly prevented with three sprayings with Bordeaux mixture.

From a careful study of the results obtained up to 1900, it was evident that, although it had been shown that the disease could be checked by spraying, there was much conflicting evidence at hand and a great many unanswered questions. Most of the experiments made were conducted for one year only. Many involved only a few trees, and many others were conducted under unfavorable conditions.

The bitter rot is a disease which has always appeared with varying virulence from year to year, sometimes destroying whole crops, then again attacking only a few apples. It has likewise made its appearance in adjoining orchards at different times in the same year. It is therefore almost impossible to draw any definite conclusions from experiments extending over one year only. Spraying in early summer may in some years check the disease should it appear only a few weeks after the spraying, while spraying at exactly the same time the next year, when the disease appears late in September, may have absolutely no effect. In order to be of value for a disease dependent upon so many varying factors as is bitter rot all spraying experiments must be conducted under exactly the same conditions in the same localities for a series of years without interruptions. Isolated tests may be and doubtless are of value in indicating what may be expected, but they are at best simply single instances, the results of which can by no means be taken as conclusive. Realizing that such was the case, a comprehensive plan for conducting spraying operations was drawn up by Mr. Waite of the Bureau of Plant Industry, U. S. Department of Agriculture, in the winter of 1900–1901, and this plan was carried out for two years in Virginia, Illinois, and Missouri, one year in cooperation with the Illinois Agricultural Experiment Station.[a] This plan was stated as follows: The object of this experiment is to answer the following questions: (1) Can Bordeaux mixture by proper spraying be made to protect apples from bitter rot? (2) Is winter treatment of the dormant trees of any assistance in the process? (3) Is early spraying more advantageous than late spraying in the treatment of this disease? (4) Are any other fungicides superior to Bordeaux mixture in the treatment of this special malady? To answer these questions the following plan was followed. The parts of the orchards experimented in were laid off in five plats, which were sprayed as follows:

Plat 1. Winter spraying only.—Spray plat and duplicate with Bordeaux mixture before the buds swell, applying the spray until the trunk and buds are blue. In duplicates, with controls.

Plat 2. Combined winter and spring spraying.—First treatment, winter spraying before buds push; second treatment, when cluster buds are open and flower buds exposed; third treatment, when the last of the petals are falling; fourth treatment, seven to ten days later. In duplicate, with controls.

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[a] This plan was described in Circular No. 43 of the Illinois Agricultural Experiment Station.

Plat 3. Early spraying without the winter treatment.—Same as above, with first treatment left off; that is, second, third, fourth, and fifth sprayings.

Plat 4. Early spraying continued until summer.—Second, third, fourth, and fifth sprayings, with four or five more treatments at intervals of two weeks until about the middle of August.

Plat 5. Late spraying.—Begin when the fruit is about an inch in diameter and spray four or five times. These sprayings may be on the same dates as the last four or five treatments of plat 4.

Before giving the results obtained from the spraying in Missouri and Illinois, it may be well to state that the bitter rot appeared in a comparatively light form during both years in which the experiments were made. The experiments illustrate once more the necessity of carrying on tests of this character for a long period of years under the same or similar conditions as previously stated. In view of the fact that the attack of the disease for the past two years was a light one in some of the orchards experimented in, the conclusions reached must be considered as preliminary ones which simply go to swell the number of isolated results of spraying operations already referred to.

Replying to the questions which are enumerated above, the following general answers may be given at this time:

(1) *Can Bordeaux mixture, by proper spraying, be made to protect apples from bitter rot?*—To a certain extent, varying from 10 to 75 per cent, Bordeaux mixture surely does prevent the ravages of the bitter rot. The extent to which it will do so will depend largely on the following factors:

(*a*) *Making the Bordeaux mixture.*—Although the literature dealing with the making of this fungicide is voluminous, there is still much of it made in an improper manner. The standard Bordeaux mixture, i. e., 6 pounds of copper sulphate, 4 pounds of lime, and 50 gallons of water, is still preferable. The copper sulphate should be dissolved in one vat; the lime in another. Only freshly slaked lime should be used, and the slaking should be brought about with small quantities of water added from time to time, so as to get an even slaking. The solutions of copper sulphate and of lime should be diluted separately and then both should be run simultaneously into a third tank. A very convenient arrangement which can be constructed anywhere is shown in figure 9. The two smaller tanks are elevated on a rough platform, high enough above the third tank to allow the solution to be turned readily into the latter. This third tank in turn is elevated sufficiently to allow the finished Bordeaux mixture to run into the tanks on the spraying wagon without pumping. Such an arrangement can be built at the edge of the pond or well, from which the water for the spraying mixture is obtained. A force pump drives the necessary water into the upper smaller tanks. Great care should be taken in weighing the proper amount of chemicals. The custom of guessing at the amounts invariably results in a poor mixture. Stock solutions of the copper sulphate, 1 or 2 pounds to the gallon, can be made and kept without deterioration, evaporation being considered.

(*b*) *On the thoroughness with which spraying is done.*—Only nozzles which throw a fine spray should be used. The Vermorel is the standard nozzle for good work. In spraying, the old precept that all parts of a tree should be reached by the spray holds good. With a fungus like that of the bitter rot, where a large number of spores may reach a fruit, thorough spraying alone will be effective. The apparent failure to control the bitter rot in many instances is doubtless due to the fact that even with the best spraying it is impossible to cover the

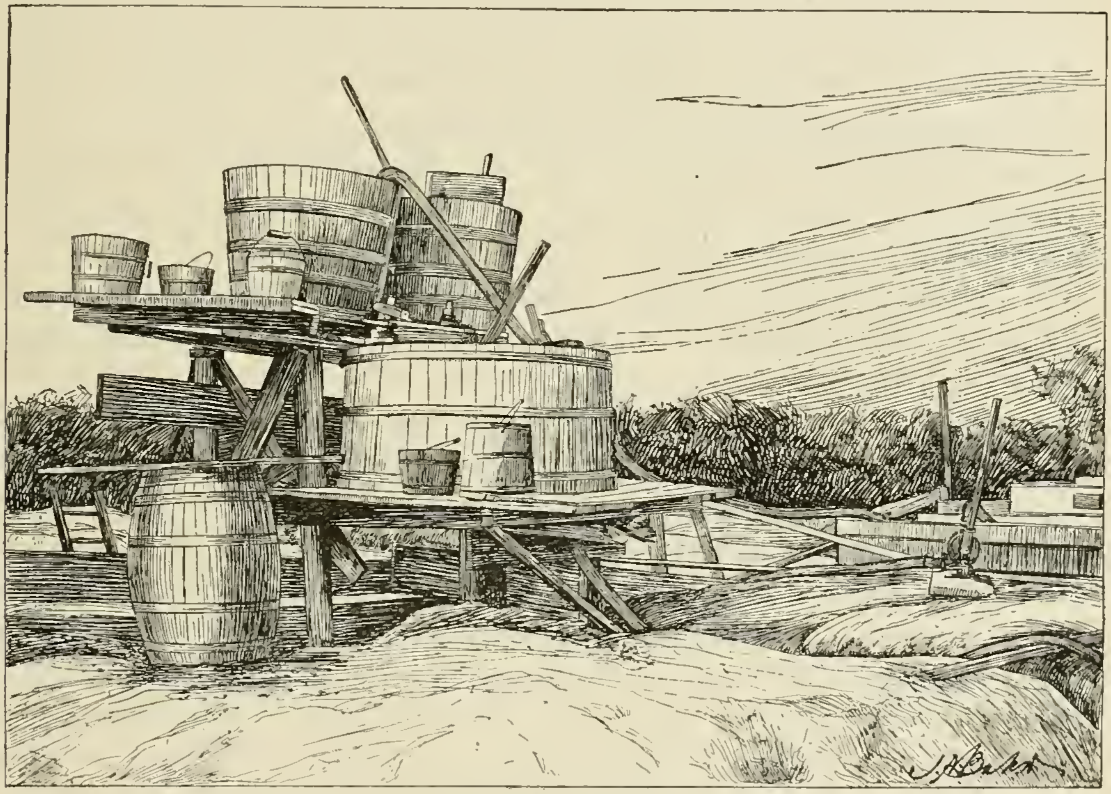

Fig. 9.—Arrangment of vats used in making Bordeaux mixture.

entire fruit with the fungicide. Numerous fruits were found on sprayed trees where the fungus had started to grow between points on the fruit covered with the fungicide. It is very desirable that further information concerning the number of sprayed fruits actually rotted be obtained.

(2) *Is winter treatment of the dormant trees of any assistance in the process?*—The spraying of trees before the buds opened showed no apparent benefit. This, however, ought not to be taken as conclusive, especially in view of the recent discovery of a stage in the life history of the bitter-rot fungus in the wood and bark of the apple tree. In the absence of any data as to the exact time when this bark stage—the canker—is reached, it may be that winter spraying will to some extent check the development of possible cankers.

(3) *Is early spraying more advantageous than late spraying in the treatment of this disease?*—No evidence was obtained from the experiments calculated to prove that early spraying is more advantageous than late spraying. The later sprayings—that is, those made after the apples were half formed—in our estimation were the most effective. The early spraying resulted in a severe rusting of the fruit during one year. The tissues of the young fruits developed very slowly under the spots where the fungicide covered the epidermis, and rusted and misshapen fruits resulted in many cases. Thick-skinned varieties like the Ben Davis showed this rusting to a marked extent. The exact explanation for this rusting as a result of spraying with Bordeaux mixture is still to be determined.

(4) *Are any other fungicides superior to Bordeaux mixture in the treatment of this special malady?*—The Bordeaux mixture is, as far as our tests go, certainly superior to any of the other fungicides used, i. e., ammonium copper carbonate and potassium sulphide.

Summing up the evidence from our own spraying operations as well as those of others, the following recommendations can be made at this time:

(1) For spraying to prevent bitter rot use the standard Bordeaux mixture, i. e., 6 pounds of copper sulphate, 4 pounds of lime, and 50 gallons of water.

(2) Spray at least once before the buds open. This spraying of the trunks and branches should be thorough, so as to reach any possible spores about to form cankers or coming from cankers.

(3) Spray during the middle of the summer, beginning about the middle of June, and continue several times until the fruit is almost ripe. Should the attack come very late in the summer, use the ammonium copper carbonate, so as to avoid damaging the fruit for the market, because of a possible lime deposit from the Bordeaux mixture.

In addition to these sprayings aimed especially at bitter rot, it is necessary to spray with Bordeaux mixture to which Paris green or some arsenical poison has been added just after the petals have fallen and again ten days to two weeks later. This is directed against apple scab, codling moth, and leaf-eating insects, as well as bitter rot and leaf blight.

SUMMARY AND RECOMMENDATIONS.

The facts presented in the foregoing pages may briefly be summarized as follows:

(1) The bitter rot or ripe rot is one of the most serious diseases of apples. The loss due to this disease in 1900 was estimated (for the United States) as $10,000,000. It is one of the most difficult diseases to control and is constantly on the increase.

(2) The bitter rot is due to a fungus, *Glomerella rufomaculans* (Berk.)

Spaulding & von Schrenk, hitherto generally known as *Glœosporium fructigenum* Berk.

(3) This fungus until 1902 was known only in its conidial stage on pomaceous fruits and grapes. The perfect or ascus stage has since been discovered both in cultures on fruits and in artificial cankers on the apple limbs.

(4) The fungus attacks ripening apples during July and August, and is most virulent during moist, hot summers. It is most active on apples in the belt of States on the line of the Ohio River, from Virginia on the Atlantic Ocean to Oklahoma in the West, and southward. (See fig. 1.)

(5) During the past summer canker-like areas were discovered on apple limbs from which the disease seemed to spread. These cankers generally occurred in the upper parts of trees and contained spores of the bitter-rot fungus, as proved by direct inoculations into apples.

(6) Inoculations into healthy apple limbs of bitter-rot spores from pure cultures of the bitter-rot fungus (made both from diseased apples and cankers) resulted in the formation of cankers similar to those found in the orchards. Spores from these cankers produced the bitter rot in sound fruits. This proves beyond doubt that the bitter-rot fungus is the cause of the cankers on apple limbs in the orchard.

(7) The spores of the bitter-rot fungus are washed from the cankers onto the apples below the cankers. Spores are carried from tree to tree by insects, and possibly by raindrops.

(8) One of the best methods for combating this disease will consist in carefully cutting out all cankers during the winter. These should be burned at once. All diseased apples on the ground or in the tree should be collected and destroyed. As a further precaution, trees should be sprayed with standard Bordeaux mixture at least once before the buds open, and again frequently from midsummer until the fruits are almost ripe.

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DESCRIPTION OF PLATES.

Plate I. Frontispiece. Apples affected with bitter rot resulting from inoculation from a canker. Two rings of spore pustules have already formed in the apple shown at the top of the plate.

Plate II. Typical examples of apples affected with bitter rot. These fruits were inoculated with spores from a diseased apple.

Plate III. A view in a Missouri apple orchard during a severe epidemic of bitter rot. Almost the entire crop of apples is diseased and has fallen from the trees within a few days.

Plate IV. Figs. 1, 3, and 7.—Apples attacked by the bitter-rot fungus at various stages of the disease. Fig. 7 shows an apple with a rotten spot only 2 or 3 days old; fig. 3, probably four or five days after the attack; and fig. 1, a little later. They all show how the diseased area becomes sunken, and later on wrinkled. They also show the rings of spore masses. Fig. 2.—An apple affected with bitter rot. The small dark spots show the appearance of early stages of this disease. Fig. 4.—A mummified apple which was attacked by the bitter-rot fungus in summer, and remained on the tree the following winter. It is dried up and shriveled. The spore masses dried, but are still present in quantities in the mummy, as shown in the figure. This illustrates the necessity for removing the mummies. Fig. 5.—Two pears, of which the one on the left was inoculated at one point with bitter-rot spores and the other pear not inoculated. After several weeks the inoculated fruit (which remained on the tree) showed a typical bitter-rot spot, with well-developed spores of the bitter-rot fungus. Fig. 6.—A small piece of a winter squash inoculated with spores of the bitter-rot fungus. The fungus grew readily on the squash, and after a brief period numerous pustules with spores formed, as shown in the figure.

Plate V. Fig. 1.—A mass of spores of the bitter-rot fungus growing in a pure culture. These spores form in countless thousands in such a culture for a period of 8 to 14 days. Fig. 2.—Various stages of germinating bitter-rot spores. Some have but one germ tube, others have two. On some of the threads dark secondary spores form. Fig. 3.—Starch grains in various stages of solution by the ferment given off by the fungus. The fungus threads growing in the cells of the apple digest the starch grains. Fig. 4.—Peculiar spore-like bodies formed by germinating spores of a cactus fungus (*Glœosporium cactorum*), which resemble the black bodies shown in fig. 2. Figs. 5 and 7.—The perfect or perithecial stage of the bitter-rot fungus as found during the winter of 1902–3 in the apple cankers. Fig. 5 shows two empty perithecia from an apple canker; fig. 7 a single perithecium much enlarged with some of the asci in place. Fig. 6.—A group of three mature asci with ascospores of the bitter-rot fungus and one immature ascus. These asci were developed in a pure culture of the bitter-rot fungus. The ascospores so much resemble the ordinary spores that it is difficult to distinguish them.

PLATE VI. Fig. 1.—A pure culture on apple agar, showing the luxuriant development of the bitter-rot fungus, with large numbers of spores. After a time this spore production stops and peculiar hard black masses develop. These masses are shown in Fig. 1. From a number of them large drops of a yellowish liquid are exuding. Each black mass contains one or more perithecia of the bitter-rot fungus, with asci, such as are shown on Plate V, fig. 6. Fig. 2.—Enlarged group of pustules on a diseased apple. On quiet, moist nights the spore masses of the bitter-rot fungus exude from the mouths of the pustules on the apple fruit in long filmy threads. Some of these threads, composed wholly of spores, are shown exuding from some of the pustules. Figs. 3 and 4.—Apple diseased with bitter rot and control fruit. These figures show the result of an experiment to determine whether the spores found in the apple cankers would produce the bitter rot in apples. A pure culture was made with spores taken from an apple canker. Spores from this pure culture were inoculated into an apple (fig. 3), while another apple was punched full of holes with a sterilized needle. As shown in the figures, the inoculated fruit (fig. 3) developed a typical case of the bitter rot, while the control fruit (fig. 4) was still sound. This is one of numerous proofs that spores from the apple cankers produce the disease.

PLATE VII. Three typical cankers such as are now believed to be formed on apple limbs during one stage in the life cycle of the bitter-rot fungus. Spores from these cankers produce the bitter rot of apples. Such cankers should be cut out and burned wherever found.

PLATE VIII. Cankers on living apple limbs. Fig. 1.—A number of cross sections of apple cankers, illustrating the manner in which the wood turns brown immediately under the dead bark. It also shows the healing callus forming at the edge of the dead areas. The largest section shows two such healing layers, proving that this canker is at least two years old. Figs. 2 and 4.—Apple branches, fig. 4 showing probably early stages of canker. Fig. 3.—A branch swollen at the point where an apple was borne the previous year. Many such were found to contain bitter-rot spores. It is possible that the fruit spurs became infected from diseased fruits through the stems of the apples.

PLATE IX. Young apple cankers produced by inoculating spores from pure cultures of the bitter-rot fungus into bark slits on healthy apple trees. In all cases here shown small cankers were formed, pustules with spores developed, and the spores, when inoculated into apples, produced the bitter rot of the fruit. This formed the last link in the chain of evidence necessary to show the connection between the bitter-rot fungus and the apple canker.

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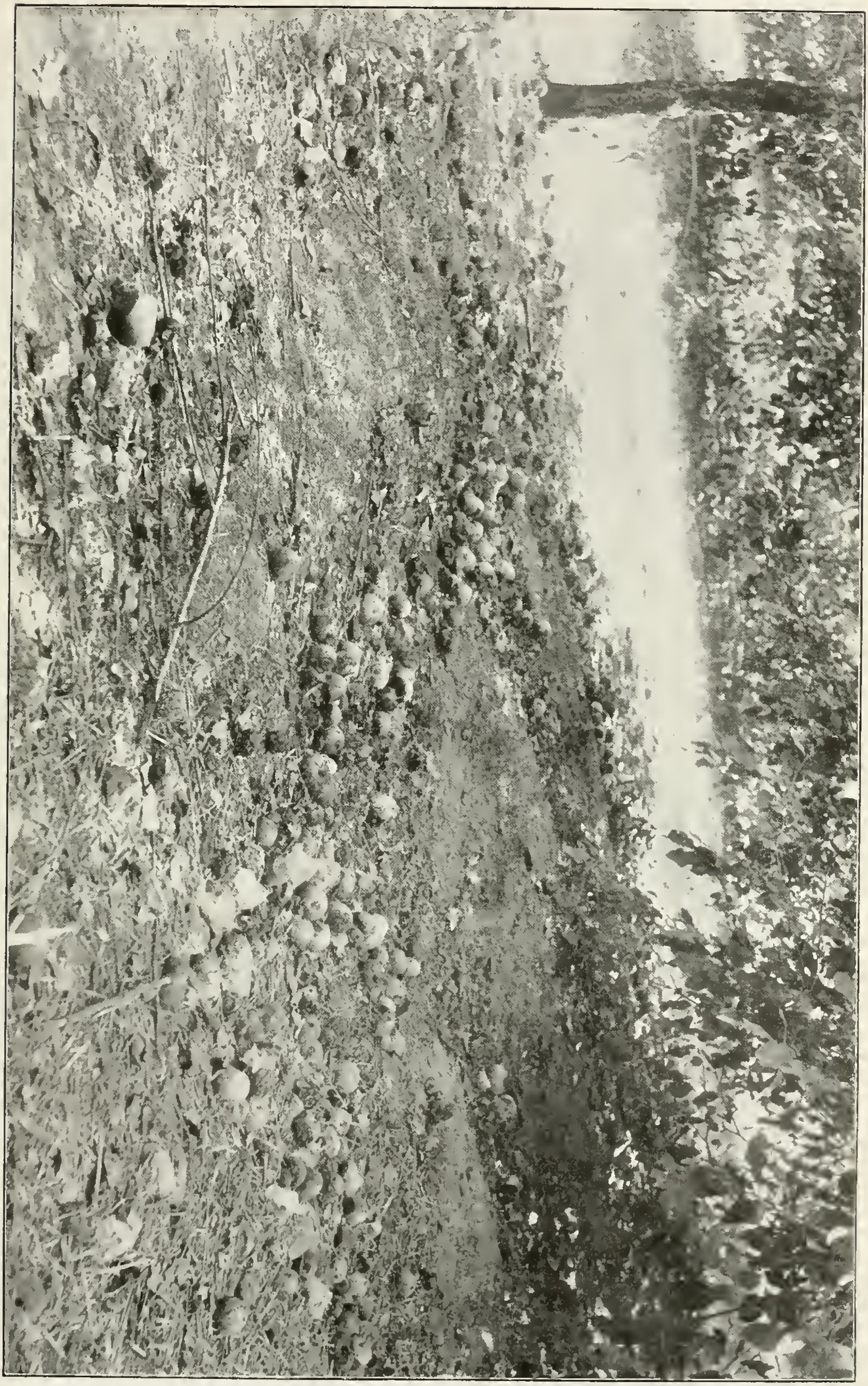
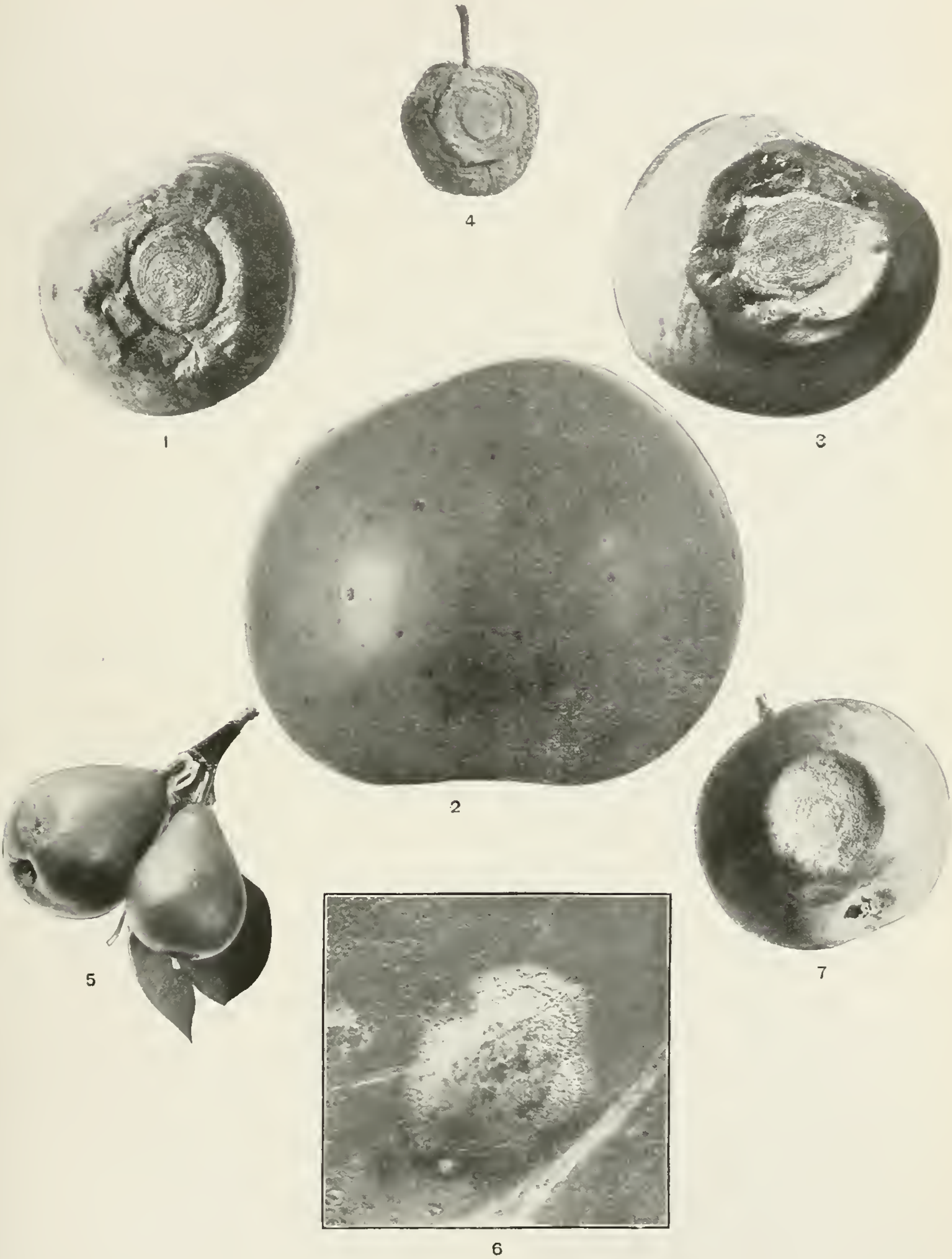
APPLES AFFECTED WITH BITTER ROT.

Inoculation from a diseased apple.

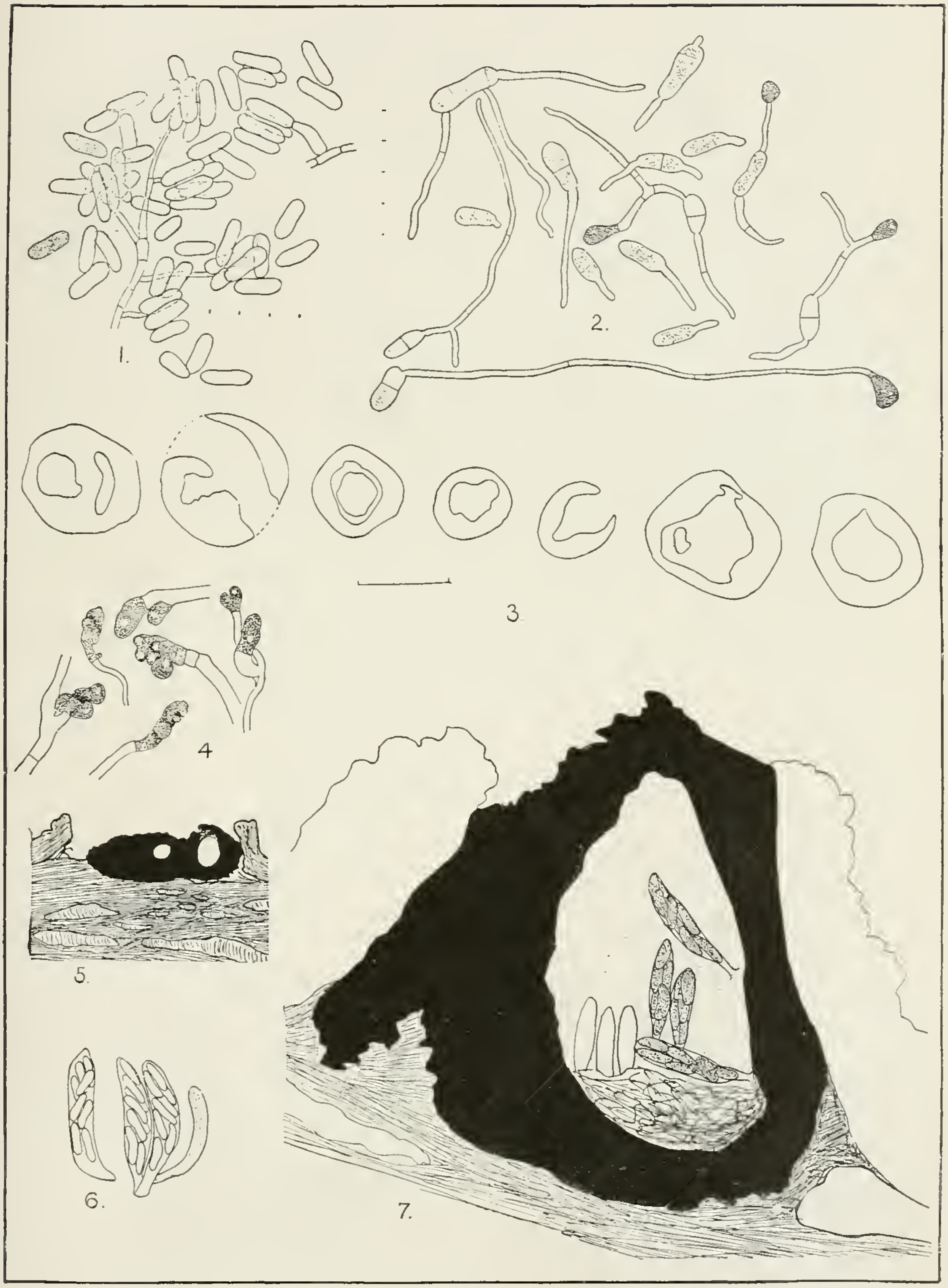


DISEASED APPLES UNDER TREES.



THE BITTER-ROT FUNGUS ON VARIOUS FRUITS.

1, 3, and 7, Various stages of growth on apples; 2, An early stage of the disease; 4, A mummified apple from the preceding year; 5, Growth of the bitter-rot fungus on pear, with control; 6, Growth of the bitter-rot fungus on squash.



VARIOUS STAGES OF THE BITTER-ROT FUNGUS.

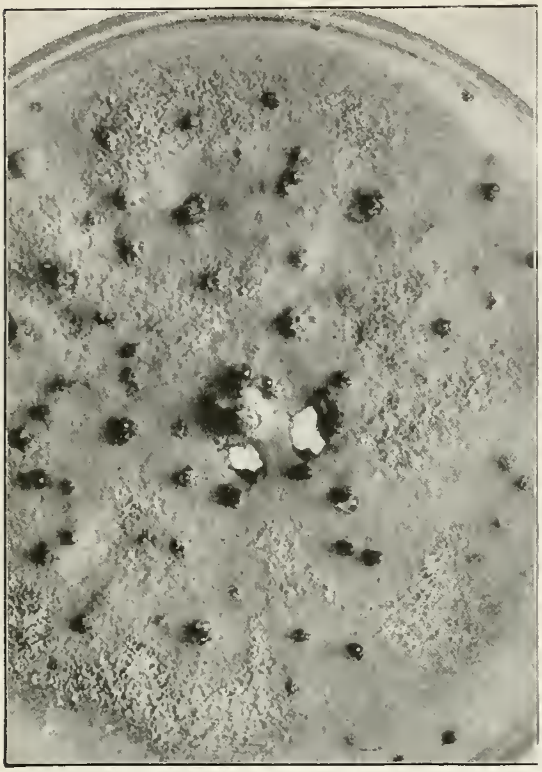


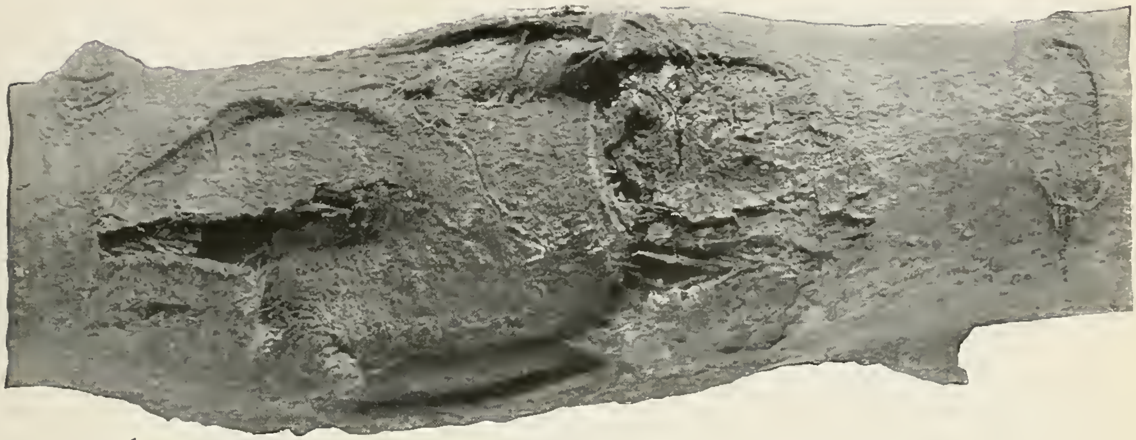
FIG. 1.—PLATE CULTURE.

FIG. 2.—PUSTULES ON APPLE.

FIG. 3.—APPLE INOCULATED FROM A PURE CULTURE OBTAINED FROM A CANKER.

FIG. 4.—CONTROL FRUIT

STAGES OF GROWTH OF THE BITTER-ROT FUNGUS.



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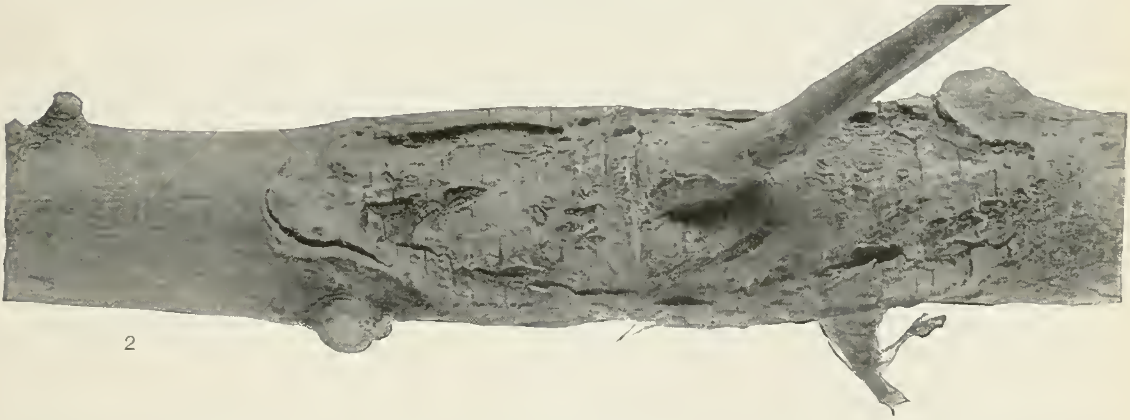

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THREE LIMBS WITH BITTER-ROT CANKERS FROM LIVING APPLE TREES.


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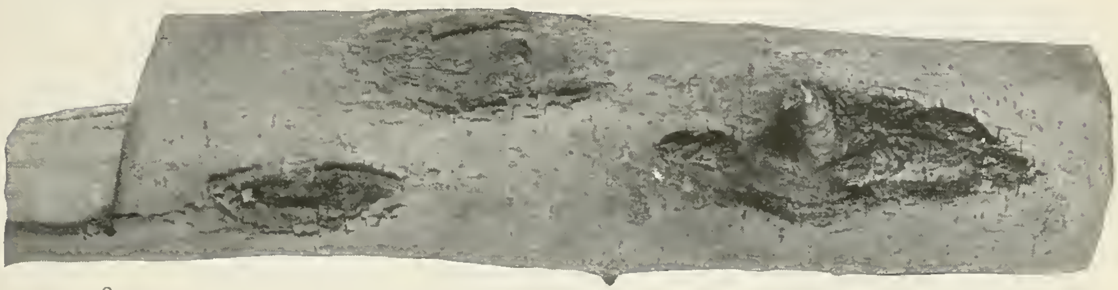
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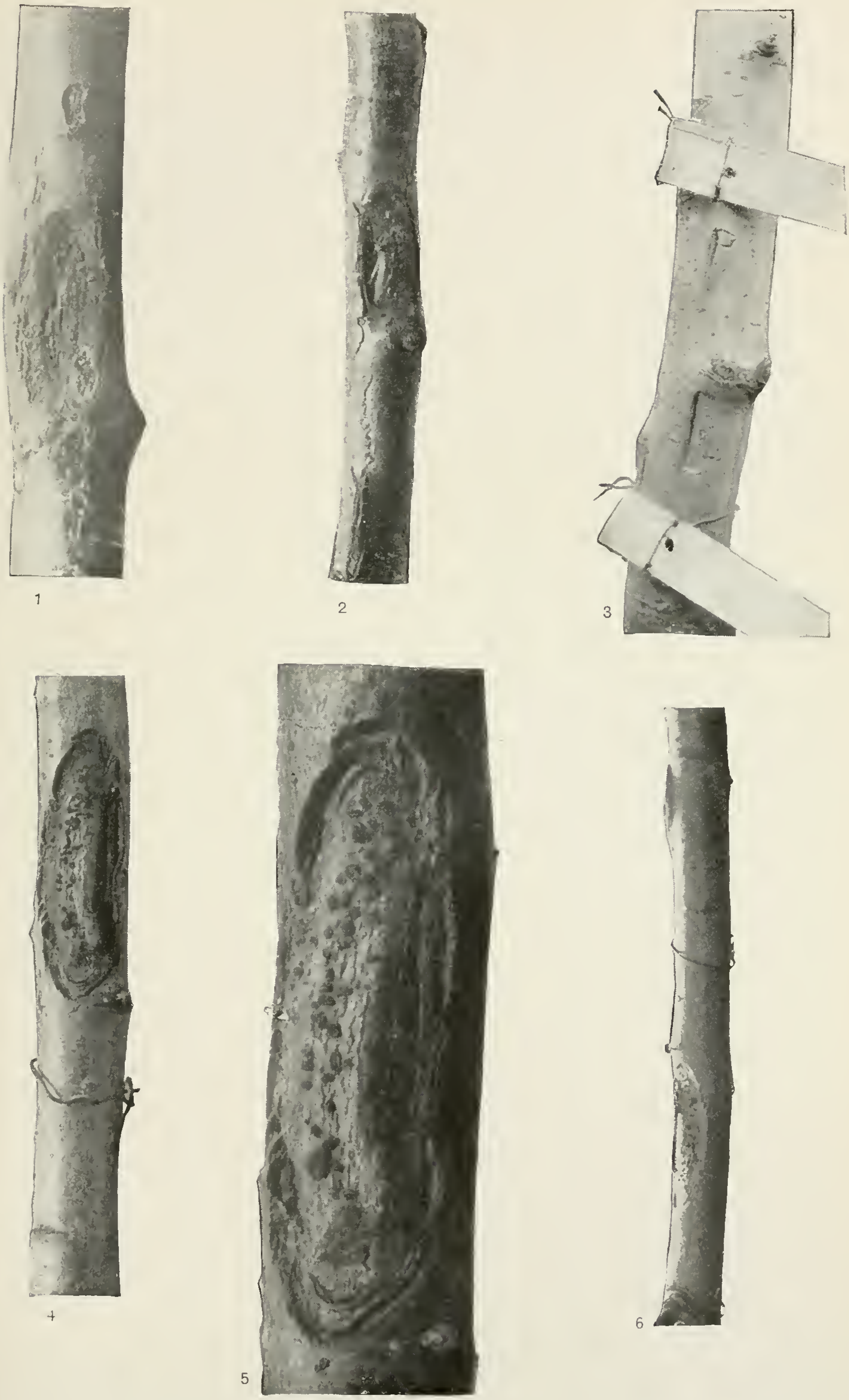
BITTER-ROT CANKERS ON LIVING APPLE LIMBS.



ARTIFICIAL CANKERS PRODUCED ON LIVING APPLE LIMBS BY INOCULATION WITH SPORES OF THE BITTER-ROT FUNGUS.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 45.

B. T. GALLOWAY, *Chief of Bureau.*

THE PHYSIOLOGICAL RÔLE OF MINERAL NUTRIENTS IN PLANTS.

BY

DR. OSCAR LOEW,

PROFESSOR OF AGRICULTURAL CHEMISTRY IN THE IMPERIAL UNIVERSITY OF JAPAN.

VEGETABLE PATHOLOGICAL AND PHYSIOLOGICAL INVESTIGATIONS.

ISSUED JULY 18, 1903.

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1903.

BULLETINS OF THE BUREAU OF PLANT INDUSTRY.

The Bureau of Plant Industry, which was organized July 1, 1901, includes Vegetable Pathological and Physiological Investigations, Botanical Investigations and Experiments, Grass and Forage Plant Investigations, Pomological Investigations, and Experimental Gardens and Grounds, all of which were formerly separate Divisions, and also Seed and Plant Introduction and Distribution, the Arlington Experimental Farm, Tea Culture Investigations, and Domestic Sugar Investigations.

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[Continued on p. 3 of cover.]

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 45.

B. T. GALLOWAY, *Chief of Bureau.*

THE PHYSIOLOGICAL RÔLE OF MINERAL NUTRIENTS IN PLANTS.

BY

DR. OSCAR LOEW,

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BUREAU OF PLANT INDUSTRY.

B. T. GALLOWAY, *Chief.*

VEGETABLE PATHOLOGICAL AND PHYSIOLOGICAL INVESTIGATIONS.

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[a] Detailed to Botanical Investigations and Experiments.

LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., May 23, 1903.

Sir: I have the honor to transmit herewith a technical paper entitled "The Physiological Rôle of Mineral Nutrients in Plants," by Dr. Oscar Loew, formerly an Expert in this Department, and recommend its publication as Bulletin No. 45 of the series of this Bureau. The paper is a revision of a former bulletin of the Department on this subject and was submitted by the Pathologist and Physiologist.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

The paper presented herewith is essentially a revision of Bulletin No. 18 of the Division of Vegetable Physiology and Pathology of the U. S. Department of Agriculture, published in 1899. The edition of this bulletin has been for a long time exhausted. In the preparation of this new edition considerable new material has been added and modifications have been made by Dr. Loew, who is now professor of agricultural chemistry in the Imperial University of Japan. It has been thought best, in view of the changes, to publish this as a bulletin of the new series.

A correct understanding of the physiological rôle of mineral nutrients lies at the foundation of all work in plant nutrition. The relation of nutrition to the health of plants and the quality of their products is receiving more attention than formerly, and is a matter of great practical and scientific importance. The purpose of this paper is to present a résumé of what has been accomplished up to the present time by the numerous investigators who have given the subject attention. The matter has been prepared, as in the former work, primarily for teachers and experiment-station workers, and it is therefore treated from a technical rather than from a practical standpoint.

Albert F. Woods,
Pathologist and Physiologist.

Office of the Pathologist and Physiologist,
Washington, D. C., May 21, 1903.

CONTENTS.

THE PHYSIOLOGICAL RÔLE OF MINERAL NUTRIENTS IN PLANTS.

GENERAL REMARKS ON THE MINERAL CONSTITUENTS FOUND IN ORGANISMS.

HISTORICAL NOTES.

The functions of the mineral nutrients in plants and animals constitute a highly important problem. Normal development is impeded by the decrease and entirely prevented by the absence of even a single nutrient, and gradual decline, disease, and finally death will result from the continued withholding of any such substance. Thus yellow spots will develop on the leaves of the sugar beet when the soil is deficient in lime; mold fungi will not develop spores but only mycelium when the amount of magnesia in the nourishing medium becomes too small; and even the primary segmentation will stop entirely in the fecundated eggs of lower marine animals when lime salts are withheld, while every further physiological action comes to an end as soon as sodium salts are substituted for potassium salts in the cells. Pigeons die in a few weeks when fed with materials too poor in mineral matter, and dogs can not subsist on meat which has been macerated with cold water, by which means most of the mineral matter is removed. The result of eating such food is weakness of the muscles and nervous excitability, which finally lead to death with spasms and the symptoms of suffocation.

In examining highly differentiated plants and animals there are observed not only certain differences as to the total sum of mineral matter in the different organs of the same organism, but also certain regularities as to the proportions of the mineral constituents. On the other hand, pathological conditions lead to a partial excretion of the mineral matter. Thus, in tuberculosis of man the excretion of lime and magnesia is increased, and in diabetes the increased excretion of lime is a specific symptom. These facts can be understood properly only when it is admitted that for the normal functions of organs a certain amount of lime and magnesia is indispensable.

Humphrey Davy[a] was the first savant to consider the mineral constituents essential for the development of plants. He says: "The chemistry of the simpler manures (the manures which act in very small quantities, such as gypsum, alkalis, and various saline substances) has hitherto been exceedingly obscure. It has been generally supposed that these materials act in the vegetable economy in the same manner as condiments or stimulants in the animal economy, and that they render the common food more nutritive. It seems, however, a much more probable idea that they are actually a part of the true food of plants, and that they supply that kind of matter to the vegetable fiber which is analogous to the bony matter in animal structures." Davy mentions among other things the beneficial action of gypsum, bone dust, and slaked lime. Indeed, the favorable effects of wood ash, bone dust, and liming upon vegetation have been known since olden times. Furthermore, mills for grinding bones existed early in the last century in France and England, and enterprising men went so far as to dig up battlefields in Europe and unearth thousands of tons of bones for agricultural purposes.

Sprengel[b] was the second one to express an opinion on this subject. He says: "We can accept it as an indisputable fact that mineral matters found in plants also are real nutrients for them, and that it is not their action upon the humus which makes them important, since gypsum, potassium sulphate, and calcium phosphate do not at all act upon the humus."[c] Boussingault (1837) also held similar views.

In quite a different sense Berzelius argued the same year that the action of lime is simply that of a stimulant for the plant and a solvent for the humus, and that lime and alkali promote the rotting of organic materials.

After Sprengel followed Liebig (1840), whose theories received substantial support in the important researches of Wiegmann and Polstorf (1842). However, great as was Liebig's merit in overthrowing the dominant theory of the nourishing qualities of organic matter called humus, in the soil, and in showing the absolute necessity of mineral salts in plants, the fact can not be denied that he made various errors, especially in his earlier years. For instance, he at one time believed that mineral bases serve merely to neutralize the organic acids in the

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[a] Elements of Agricultural Chemistry, London, 1814.

[b] Theorie der Düngung, 1839.

[c] As a significant fact it may be mentioned that the Prussian Academy of Sciences in the year 1800 offered a prize for an investigation to decide whether the mineral matters found in plants are taken up from the soil or whether they are produced in the plants themselves by vital power. This question was treated by Schrader, whose decision was in favor of the latter opinion. How much farther advanced was Saussure, who in 1804 declared that the mineral matter of humus contributes in a certain degree to its fertility, since the same is found in the ashes of the plants (Récherches sur la végétation). Senebier entertained the same view.

plant and that they could replace each other, and, further, that alkaloids in plants could play the part of mineral bases. He ascribed certain diseases of plants solely to the deficiency of mineral matter in the soil, but later investigations have demonstrated that fungous or animal parasites are the true causes. After about twenty years of hard fighting the importance of Liebig's mineral theory was in the main recognized and the old humus theory abandoned. However, his opinion that the mineral bases replace each other has been proved to be erroneous by the experiments of Wolff, Knop, Hellriegel, and others. The indispensability of potassium was proved, especially by Friedrich Nobbe, Schroeder, and Erdmann (1871), as was also the noxious character of lithium salts for phanerogams. Salm Horstmar and Stohmann furnished evidence that lime and magnesia can not replace each other.

When Liebig had called attention to the necessity of certain mineral constituents in plants he set his assistants and students at work to analyze the ashes of a great number of plants. He published an account of these analyses in his works on agriculture, but a more comprehensive review on plant ashes is given in the tables of E. Wolff.[a]

These results show that the quantitative composition of the ash of one and the same plant varies according to the soil upon which it is grown, but that qualitatively there is no difference. This observation, which led Liebig to erroneous assumptions, was properly explained much later. It was found that every plant absolutely requires a certain minimum of each mineral nutrient, and that in most cases besides this minimum it takes up not only an excess of these various compounds, but also substances which are perhaps useful but not absolutely necessary for plant functions, such as sodium salts and silica. In the case of potassium or calcium salts a moderate surplus is not noxious. A large excess of lime taken up can be easily excluded from secondary influences by transformation into oxalate or carbonate—salts which are often produced by plants. Plants adapted to saline desert soils show incrustations on their leaves, which may sometimes contain, in addition to chlorid, nitrate, and sulphate of sodium, more than 50 per cent of calcium carbonate.

The surplus of mineral matter found in plants—nutrient as well as indifferent compounds—depends to a great extent upon the intensity of the current of transpiration, which explains why herbaceous plants show a higher percentage of ash for the dry matter than do the leaves of woody plants. While cabbage leaves, which have about 90 per cent water, contain 15 to 18 per cent ash for the dry matter, the leaves of potatoes, clover, and grass, having 78 to 80 per cent water, contain only 6 to 9 per cent ash for the dry matter. In trees adapted to moist soil—for instance, *Salix*, *Populus*, *Acer*, and *Tilia*—the leaves contain

[a] Aschen Analysen (2 volumes), Berlin, 1871 and 1880.

more water and also generally more ash for the dry matter than do the leaves of trees in which transpiration goes on more slowly, such as *Quercus*, *Fagus*, and the common kinds of *Pinus*. While leaves of *Acer* show 7 to 9 per cent of ash and those of *Salix* 4 to 6 per cent, the leaves of *Pinus montana* and *P. austriaca* show only 0.58 per cent and 0.74 per cent, respectively (Ebermayer). There is more ash in the leaves than in the roots or stems, more in the roots and stems than in the seeds, and more in the seeds than in the wood.

MINERAL COMPOUNDS FOUND IN ORGANISMS.

The mineral compounds chiefly found in living organisms contain phosphates, sulphates, carbonates, and chlorids, magnesia, lime, soda, potash, iron compounds, and silica. Small quantities of iodin and fluorin compounds are also found in both kingdoms. Bromin compounds occur in seaweeds. Occasionally there are present in plants small quantities of titanic and boric acids, lithia, and alumina, and of the oxids of lead, zinc, and copper.[a] Sodium salts are not necessary for physiological uses of plants, but are for those of animals. Calcium salts are of great importance for plants and animals, only the lower fungi and lower algæ being able to do without them. Magnesium and potassium salts, however, can not be dispensed with by any living cell any more than can phosphoric acid. Manganese, which was shown by Risse to be incapable of replacing the iron in plants and was believed to be entirely useless, forms, according to recent researches of Bertrand, a frequent constituent of the vegetable oxidizing enzymes.[b] Manganese also was found in the animal body. The nitrates and sulphates present in plants serve chiefly as sources of nitrogen and sulphur for protein formation, and consequently do not require further discussion. As physiological elements these must be designated: Potassium, sodium, calcium, magnesium, iron, phosphorus,

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[a] Lippmann observed in the sugar beet not only boric acid and copper oxid, but also traces of vanadin, rubidium, and cæsium compounds. Wait found 0.31 per cent titanic acid in the ash of oak wood, 0.11 per cent in the ash of apples, and traces of it in bones and meat, and Dunnington found it in many soils. Recently traces of arsenic were observed in normal animals, especially in the epidermis, by Gautier and Bertrand. Copper has been found in the liver of Cephalopoda by Fréderique and by Henze, further in plant ash by MacDougal, Heckel, and others, while Demarcay has identified vanadium, molybdenum, and chromium compounds in the ash of certain plants. *Arabis halleri* (Fricke) and *Viola calaminaris* thrive on soils rich in zinc, while *Amorpha canescens* grows well on a lead soil.

[b] According to Lepinois, iron can replace manganese in the oxidizing enzymes. Woods has further observed the presence of oxidase in plants grown in the absence of manganese. Oxidases, however, act more powerfully in the presence of manganese than of iron (Bertrand).

chlorin, iodin, fluorin, carbon, hydrogen, nitrogen, oxygen, sulphur, and silicium.

VARIETY OF FUNCTIONS OF MINERAL SUBSTANCES.

A question of fundamental importance is whether a certain mineral constituent has one or several functions to perform, and in the latter case whether at least one of these several functions may not be performed by some other related constituent—in other words, whether a partial substitution in the organisms would be possible. When a mere neutralization of acids or an osmotic action is involved there can be no doubt that potash or lime may be replaced by soda, or when incrustation of a tissue is necessary for protection the place of calcium carbonate might be taken even by silica. The solution of various mineral salts produces osmotic pressure and motion required also by animals. Thus beef tea containing 0.35 gram of salts per liter exerts an osmotic energy of several atmospheres, of which, however, only about one-fourth can be realized in the stomach, since the blood itself also contains mineral salts. However, it suffices to produce an aqueous current from the blood to the stomach, while in the intestines the current takes the opposite direction.[a] Such functions are not specific, however. In the purely physiological functions of a chemical nature not even a partial substitution is possible, notwithstanding that various assertions have been made to the contrary. In the living protoplasm potassium can just as little be replaced by sodium as carbon by silicium.

There exist physical and chemical functions, as well as ecological and physiological rôles. A further distinction may be drawn between elements absolutely necessary and such as act merely beneficially. Sodium, manganese, and silicium in the phanerogams belong to the latter group. A physical function is performed by the calcium phosphate in the bones, by the silica in the shells of *Radiolaria* and *Diatomeæ*, and the calcium carbonate in those of *Foraminiferæ*, mollusks, and birds' eggs. The protection against snails afforded to certain leaves by the needle crystals of calcium-oxalate is an example of an ecological rôle, as is also the free sulphuric acid secreted by certain *Gastropoda*, as *Dolium* and *Cassis*.

In order to furnish a foundation upon which to base a theory of the special functions of the various mineral constituents, separate analyses for each kind of organ are indispensable. In former times entire plants or animals were subjected to incineration and the ash analyzed, but such results were of very restricted value.[b]

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[a] Köppe, Therap. Monatshefte, 1897.

[b] Thus one author has inferred from his analyses that there is less magnesia in cats than in dogs and less potash in dogs than in rabbits. (Zeitschr. f. Biologie, Vol. X, p. 321.)

GENERAL VALUE OF CERTAIN MINERAL SALTS.

Mineral salts have not only to perform physical as well as specific chemical functions,[a] but also seem to contribute directly to the maintenance of the living condition of the protoplasm. A most striking instance of this is the rapid dying of infusoria in distilled water. The writer entertained for a time the supposition that this phenomenon might be due, as in the case of the alga *Spirogyra*, to slight traces of copper sometimes found in distilled water and derived from the copper vessels used in distilling. Experiments were therefore repeated, water distilled from glass vessels being used, but the effect was the same—the infusoria died with bloating, their protoplasm swelling and disintegrating. The only conclusion that can be drawn, therefore, is that the distilled water extracts from them traces of necessary constituents, which must be mineral, since common water containing some mineral matter has no such action, but forms the very medium of existence for these organisms. A similar effect could not be observed with the same distilled water on algæ cells, which may remain alive in it for a considerable time, although the growth ceases. But here the walls of the cytoplasm are probably of greater density, which would prevent the mineral matters of the cell from passing easily to the outside.

This phenomenon observed in the case of infusoria strongly resembles that of the red blood corpuscles and leucocytes, which are adapted to the degree of concentration of the serum, and which die when transferred into distilled water, but remain alive for some time in a sodium-chlorid solution of 0.6 per cent. The nature of the mineral salts loosely bound by the proteids of the living matter may vary with the character of these proteids. In the one case it may be sodium chlorid, in another the secondary potassium phosphate, and in a third a calcium salt. It should be pointed out once for all that we can hope to understand the living state of protoplasm only when the proteins of the living matter are recognized to be chemically labil bodies, which the slightest influence often suffices to transform into the more stable isomeric forms of dead matter. Relatively stable proteins are also those in milk and the reserve proteins in eggs and seeds. Spontaneous transformations of labil compounds into stable ones by atomic migration often take place very easily—for example, when certain amido aldehydes or amido ketones are liberated from their combination with acids.

Years ago M. Nencki[b] recognized the importance of the mineral

[a] Certain salts may also exert a stimulating action, that is, some fluorids, iodids, and manganese and uranium compounds, as has been shown by recent work of the writer in conjunction with Messrs. Nagaoka, Aso, Sawa, and Suzuki. Great care must be exercised in the use of such stimulants, since in certain amounts they act as poisons rather than as stimulants.

[b] Arch. des Sci. Biologiques de St. Petersburg, 1894, Vol. III, p. 312.

matter combined with the plasma proteids. "All proteins[a] occurring in the living organisms are combined with mineral substances, whereby the proteins concerned acquire specific properties and functional signification in the organisms."

Since in a normally developed plant each nutrient must be present in definite amount, it is evident that normal growth can not be expected when any one of the mineral nutrients is present in insufficient quantity, no matter what amount of the other mineral nutrients may be available. The production of the organic matter of a plant of definite size depends therefore upon that mineral nutrient which is present in relatively smallest amount. For example, it is clear that the division and multiplication of cells depends upon the development of the nucleus, and that upon the continuous formation of nucleoproteids. Hence when phosphoric acid is present in but small amount, only a corresponding amount of nucleoproteid can be produced. This holds good likewise for lime, since we infer that the lime compounds of nucleoproteids are concerned in the building up of the nucleus. Potassium is essential to organic synthesis. Accordingly when but little potassium is available, the organic matter in the plant will depend on this amount, no matter what amount of the other mineral nutrients be at hand. This fact, which means that the size of the harvest depends upon the mineral nutrients present in least amount, is known as *Liebig's Law of the Minimum.* Liebig inferred this law from general principles and without any knowledge of the special function of each mineral nutrient.

It may be proper here to call attention to another phenomenon, first recognized by Wolff. He determined the minimum of each mineral nutrient necessary for the normal development of the oat plant when the other mineral nutrients were in excess, and found that when all the mineral nutrients are offered in the determined minimum amounts at the same time it is impossible for the plants to flower and fruit normally. When only the absolutely necessary minimum of one of the nutrients is offered a certain surplus of some of the others must be present.

THE LOW ATOMIC WEIGHT OF THE MINERAL NUTRIENTS.

A review of the elements necessary for organic life shows at once that they have low atomic weights, iron, with an atomic weight of 56, having the highest among them. This is due, according to Leo Errera, not only to their more frequent occurrence in the various compounds making up the earth's crust, but also to their higher specific heat.

[a] While "protein" is the general denomination of all kinds of albuminous substances, the word "proteid" applies especially to the complex proteins, e. g., nucleoalbumin, mucin, hæmoglobin, etc.

Thus water, constituting as a rule two-thirds to three-fourths and sometimes even more of the weight of a living organism, has the highest specific heat of all substances; consequently it can diminish the effects of rapidly changing temperatures upon life.

THE PHYSIOLOGICAL RÔLE OF PHOSPHORIC ACID.

RELATION OF PHOSPHORIC ACID TO PROTEIDS AND TO THE DIVISION OF CELLS.

Phosphoric acid is, above all, necessary for the formation of lecithin[a] and the nucleoproteids, e. g., chromatin[b] and plastin, the most essential constituents of the nucleus and plastids. This makes clear the statement of former writers that phosphoric acid "follows the proteids," since every new cell requires them. Wherever phosphoric acid is transformed from the dissolved condition to an insoluble compound, as in the formation and growth of the nucleus, fresh supplies must move thither, according to the law of diffusion. The embryos can develop by cell division only when phosphates are stored up in sufficient quantities in the seeds for the formation and increase of the nuclear substance in the new cells. Phosphoric acid, further, is not only contained as calcium and magnesium phosphate in the globoids, but is also distributed in the seeds as dipotassium phosphate.

The observation that the total mass of protein in seeds is increased by an increased supply of phosphoric acid would also be easily understood on the basis of the hypothesis of Strasburger and Schmitz that the nuclei are the manufacturers of the protein matter. This hypothesis is highly probable, and in fact has been confirmed by Hofer in the case of enzymes,[c] which must, partially at least, be considered as a class of proteins.

The yield of grain is much more increased by phosphoric acid than by nitrogen or potassium compounds.

In order to observe how a deficiency of phosphoric acid would interfere with the normal action of plant cells the writer compared at a low temperature the behavior of algæ (*Spirogyra*) in complete culture

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[a] Two other phosphoric acid compounds, which are, however, restricted to the higher animals, are jecorin and inosic acid, the latter probably being merely a product of metabolism. Besides phosphoric acid, the latter yields on decomposition hypoxanthin and probably trioxyvalerianic acid (Heuser). Another compound, thus far encountered only in plants, yields, besides phosphoric acid, inosite (Schulze and Winterstein). This compound is considered by Posternak to be oxymethyl phosphoric acid.

[b] The nuclein extracted from organized structures is essentially an altered chromatin. It contains metaphosphoric acid (Liebermann).

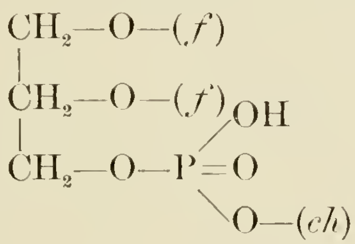
[c] Sitzungsberichte der Morph. Physiol. Ges., Munich, 1889.

solutions[a] with that of algæ cultivated for eight weeks in solutions free from phosphoric acid, but containing all other necessary mineral nutrients. The result was that there was no growth in the absence of the phosphoric acid, but there was a yellow coloration of the chlorophyll and an accumulation of fat and albumin, while in the control algæ the number of cells had more than doubled, the coloration of the chlorophyll was normal, and the amount of fat and albumin stored up was much smaller than in the former case. When, however, at the end of eight weeks 0.1 per mille of monopotassium phosphate was added to the culture free from phosphoric acid, a most energetic cell division began in most of the cells after a short time, thus demonstrating the great importance of phosphoric acid for this purpose.

A direct participation of inorganic phosphates in the formation of albumin, as Liebig had assumed, has not been proved, and is improbable. As the writer has observed, cells of algæ can continue to form albumin for a certain length of time, even in the absence of inorganic phosphates, although further growth and multiplication will be stopped.[b]

THE PHYSIOLOGICAL IMPORTANCE OF LECITHIN.

This ester of phosphoric acid contains fatty acids, glycerol, phosphoric acid, and choline, and corresponds to the following formula:[c]



It is a regular concomitant of fatty matter. It swells up in water and is even somewhat soluble in it, a property which renders it physiolog-

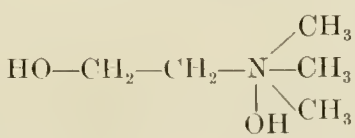
[a] The composition of the solution made with distilled water for the control culture was as follows:

	Per mile.
Potassium nitrate	0.2
Calcium nitrate	.2
Sodium sulphate	.1
Magnesium sulphate	.1
Monopotassium phosphate	.1
Ferrous sulphate	Trace.

The monopotassium phosphate was left out in one of the solutions.

[b] Biol. Centralbl., 1891, Vol. IX, No. 9.

[c] (*f*) Signifies the radical of a higher fatty acid; (*ch*) signifies the radical of choline:



ically superior to the ordinary fatty matter. The chief function of lecithin is probably to serve for respiration; it represents the form into which the fat must be changed to become combustible in the protoplasm, since the substances serving for respiration must be present in the protoplasm in a dissolved condition.[a] Since fat is not soluble, a transformation of it into soap was formerly assumed, a view which is hardly possible in the case of plants, while upon animals soaps injected subcutaneously exert a poisonous action (Munk, 1889).

By the transformation of fatty matter into lecithin the higher fatty acids are offered to the protoplasm in a soluble form, and after being oxidized other molecules of fatty acids may enter into the place of the former and thus the same molecules of the glycerol-phosphoric acid can serve repeatedly as vehicles for oxidations of molecules of fatty acids. The fact that blood corpuscles contain lecithin but not fat seems to indicate that lecithin may be produced not only from fat, but also directly from sugar, as is fat. A great therapeutic value of lecithin has been demonstrated in cases of nervous debility and weakness of the alimentary functions. The brain and the whole nervous system in general are rich in lecithin, fully 17 per cent of it having been found in the gray substance of the brain. The nervous system requires for its unceasing activity a substance which unites easy combustibility with a great deal of potential energy in a small volume, which conditions are admirably united in the lecithin.

Seeds rich in starch generally contain much less lecithin than those rich in protein. Thus, barley grains contain less than half the amount contained in soy beans. The amount of lecithin increases to a certain point in the first stages of germination, while the amount of fat decreases.[b] Here the lecithin is evidently formed from the fat. It seems very probable that the observed increase of lecithin is less than was actually formed, since a part of it is probably consumed nearly as quickly as produced. The evergreen tea leaves lose the reserve lecithin in spring (Hanai), and green plants generally lose it when kept in the dark (Stoklasa). Heffter observed a decrease in the amount of lecithin in the liver during starvation. E. Schulze[c] found that during germination the quantity of choline increases, and that in wheat the choline is localized in the germ of the grain, but not in the endosperm. This is certainly of physiological interest, since the young developing germ must carry on an energetic respiration and therefore be capable of easily forming lecithin, in which process the presence of choline is

[a] We can observe this with cholesterin, which is frequently contained in the cells and, in fact, is, like lecithin, a constant concomitant of fatty matter. It is not perceptibly oxidized by the protoplasm, the almost absolute insolubility in water being here the obstacle.

[b] Maxwell, Chem. Centralbl., Vol. XLI, No. 1, p. 365; Frankfurt, Landw. Vers. Stat., Vol. XLIII.

[c] Landw. Vers. Stat., Vol. XLVI.

required. It may further be mentioned in this connection that, according to Müntz, the amount of free fatty acids increases during germination, which is to be expected when lecithin is formed from fat. From all the observations cited it will be seen that lecithin plays an important rôle; and as its formation is made possible only when phosphoric acid is present, one of the functions of this acid at once becomes intelligible.

PHOSPHORIC ACID IN CHLOROPHYLL.

As Trécul, Gautier, and Hoppe have shown, the crystallized chlorophyllan also contains phosphoric acid (1.39 per cent); indeed, for the formation of the chlorophyll green the presence of phosphoric acid is absolutely required (see p. 21). The opinion has been expressed that the crystallized chlorophyllan is a kind of lecithin. Others, however, have declared it a mixture.

POTASSIUM PHOSPHATE AS A CELL CONSTITUENT.

That the secondary potassium phosphate as such has also an important physiological function becomes probable from its general occurrence in the living organisms. Relatively large proportions of it are found in yeast cells, in seeds, in the liver and muscles, and, in fact, in all cases where special demands for great chemical achievements are made. It causes the weak alkaline reaction of protoplasm and is probably present in loose combination with certain proteins, from which even treatment with water will often easily remove most of it. A further special function of phosphoric acid is the use of calcium phosphate for the formation of bones. The blood ash of cattle contains 4 to 6 per cent and of man 9 to 11 per cent of phosphoric acid.

The dry substance of muscles contains about 4 per cent of mineral matter, of which again nearly two-thirds consist of dipotassium phosphate. This is also nearly the proportion found in beer yeast. Wheat grains contain from 1 to 2 per cent ash, of which nearly one-half consists of potassium phosphate and nearly one-fourth of calcium and magnesium phosphate, while another portion of phosphoric acid present in that ash is derived from the destroyed nuclein and small portions of lecithin.[a]

The requirements for normal field crops are considerable, a wheat crop, for example, extracting from 1 hectare (about 2.5 acres) of ground about 26.5 kilos of this acid. The forest products require much less. It is in the production of seeds especially that the powerful influence of fertilization with phosphates becomes apparent.

[a] Several views have been expressed as to the transportation of calcium phosphate to the seeds. This salt is insoluble in water, but may be dissolved in small quantities by the weak acid juices of the plant. Vaudin (Chem. Zeitung, No. 91, 1895) believes that its transportation in the vegetable organism is accomplished by sugar and potassium malate or citrate, which dissolve it in small quantities.

Whether hypophosphites, phosphites, or hypophosphates can ever be of physiological value is a question which must be determined by further studies. Knop showed in an experiment with maize in 1881 that phosphoric acid can not be replaced by hypophosphoric acid. The writer has observed that algæ are at least not injured by a 1 per mille solution of sodium hypophosphite, phosphite, or pyrophosphate and metaphosphate, and the two last-mentioned salts can even be well utilized by mold fungi.[a] The assertion once made that phosphoric acid in algæ may be replaced by arsenic acid is absurd, and moreover Molisch had shown it to be impossible.

THE PHYSIOLOGICAL RÔLE OF SILICA.

Ritthausen, as well as Wolff (1880), arrived at the conclusion that the rôle of silica in the leaves consists in causing the dying off of the leaves during the ripening of the fruits, since from these dying leaves phosphoric acid and other mineral nutrients are transported to the ripening seeds. Experiments carried on for fourteen years have shown Wolff that plants yielded empty grains (taube Körner) when a certain excess of phosphoric acid was not offered. But in the presence of silica this excess was not necessary, since it could be drawn from the leaves when dying off sooner under the influence of silica. Hence, silica can be considered a means to economize the phosphoric acid in the soil.

In some barks (*Carpinus*, *Acer*) so much silica[b] was found that a certain value seems probable. Sometimes also the fibrous materials are relatively very rich in silica; the ash of linen fiber was found to contain fully 28.2 per cent.

In the case of animals silica seems to play a rôle in the formation of hairs and feathers, since these contain an organic silicium compound (Drechsel). Various organs of animals contain small amounts of silica, but young animals contain in the same tissues more SiO_2 than older ones (Schulz, 1902). The pancreas is especially rich in silica, 12.3 per cent of its ash being SiO_2 (Faulhaber, 1899). Human hair contains from 0.10 to 0.23 per cent SiO_2 (Kall).

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[a] Bot. Centralbl., 1895.

[b] It has been asserted that the siliceous deposit in the bark of *Fagus* and *Acer*, and in the leaves of various other plants, forms a protection against parasitic fungi. (Forstlich-naturwissenschaftliche Zeitschrift, 1893, p. 224.)

THE PHYSIOLOGICAL RÔLE OF IRON COMPOUNDS.

RELATION BETWEEN THE COLORING MATTER OF THE BLOOD AND OF THE LEAF.

Iron compounds are indispensable for the production of the chlorophyll[a] of the plant and of the hæmoglobin of the red blood corpuscles of the higher animals. Without the former there is no assimilation of carbonic acid, hence no synthesis of organic matter in the green plant, and without the latter no respiration of the vertebrates, since it is the hæmoglobin that carries the molecular oxygen to the remotest regions of the body. Although the chlorophyll itself does not contain iron, hæmoglobin contains it as an essential constituent of the molecule.

There is evidently a close relation between the coloring matter of the leaf and that of the blood. The phylloporphyrin obtained from chlorophyll by the action of alkalis shows almost the same spectrum as the hæmatoporphyrin obtained from the hæmoglobin of the blood. Hæmatoporphyrin seems to correspond to a dioxyphylloporphyrin, and both of these compounds appear to be derivatives of pyrrol. It was especially the investigations of Nencki and of Tschirch that first directed attention to the analogies between these two physiologically important bodies.

INFLUENCE OF IRON AND OTHER MINERAL NUTRIENTS ON THE FORMATION OF CHLOROPHYLL.

Iron is not the only requisite for the production of chlorophyll. Other mineral nutrients are not less necessary, and above all only a normal plastid can produce the green color with the aid of iron salts and thus become a chloroplast; hence cases of imperfect plastids may occur, e. g., where an increased supply of lime is required to produce normally green leaves. A case where phosphoric acid was required in addition to the iron to produce the chlorophyll was observed by the writer in the case of an alga. Some threads of *Spirogyra majuscula* were placed in 2 liters of distilled water, to which were added only 0.2 per mille calcium nitrate and 0.02 per mille ammonium sulphate. When they were placed in this very imperfect solution the filaments contained, in all probability, some stored-up mineral matter, hence a moderate further growth of the cells was not surprising. Besides, mineral

[a] An observation on chlorophyll made by the writer may here be mentioned, as it demonstrates beyond a doubt the great sensibility of this substance toward chemical reagents. When *Spirogyra* threads are treated with moderately concentrated hydrochloric acid, they at once assume a yellowish color, but soon afterwards turn to a bluish green, which points to two successive changes and indicates that in the preparation of pure chlorophyll strong acids have to be avoided. Various discrepancies in the observations of different authors may be traced to this circumstance.

matter of some cells which died gradually may have been absorbed by the living ones. The cells did not increase by cell division, however, but merely enlarged. After standing six weeks the chlorophyll bodies had assumed a yellow color. The liquid, with the filaments, after the addition of 0.02 per mille ferrous sulphate, was now divided into two portions, and 0.5 per mille secondary sodium phosphate was added to one of them. After five days a very striking difference was noticed, the normal green reappearing only in the latter case, which proved that phosphoric acid is an essential factor for the production of chlorophyll. Stoklasa also has observed the necessity of phosphoric acid for the production of the chlorophyll green, and finally Macchiata[a] inferred from his experiments that plants may become chlorotic not only from a deficiency of iron, but also from lack of other mineral nutrients. Indeed, cases exist in which it is the deficiency of magnesia which causes this phenomenon (p. 58).

An interesting fact observed by Zimmermann[b] is that the chloroplasts in chlorotic leaves are smaller than in normal leaves, and appear to be incapable of forming starch from sugar. Different from chlorosis is the albinism of plants. Here the leucoplasts have so far degenerated that they become incapable of producing the green color, even when all the necessary mineral nutrients are present. Although incapable of forming carbohydrates from carbonic acid, however, they often form starch from sugar.[c]

FERTILIZING EFFECT OF IRON SALTS.

It is to be expected that a moderate manuring with iron salts would prove beneficial for plants grown on soil deficient in iron. Bracci[d] mixed 1 part of ferrous sulphate with 20 parts of silt and applied this mixture to soil in which oats and wheat were grown, and as a result the grain ripened several days earlier and the yields of straw and grain were increased. Spraying with ferrous sulphate is also said to produce favorable results. Ville applied a 2 per cent solution to young apple and pear fruits,[e] and thus not only hastened the ripening process, but also enlarged the size of the fruit. Cugini seeks to explain this on the ground of stimulation of the protoplasm and increased production of chloroplasts in the epidermis.

ORGANIC COMPOUNDS CONTAINING IRON.

Hæmoglobin is not the only organic iron compound in organisms. Bunge isolated from the yolk of eggs a nuclein-like body, hæmatogen,

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[a] Bot. Jahresber., 1888, p. 20.

[b] Zimmermann, Beiträge zur Morph., etc., Heft II; Sapoznikoff, Bot. C., 1889, p. 321.

[c] Bot. Jahresber., 1888, p. 20.

[d] Bot. Jahresber., 1883, p. 43.

[e] Bot. Jahresber., 1883, p. 14. Other reports, however, mention an injurious action of a 1 per cent solution upon potato plants.

which contained 5 per cent phosphorus and 0.23 per cent iron, and similar substances were observed by Zaleski in the liver of animals, and by Macallum, Stoklasa, and Suzuki in the nuclei of plant cells. Spitzer found in animals oxidizing enzymes, which were nucleoproteids containing about 0.2 per cent of iron.

IRON IN FUNGI.

The question as to whether iron salts are necessary for fungi was formerly answered in the negative. Mòlisch,[a] however, observed that even very small traces of iron salts have a great effect upon the growth of fungi, and having discovered traces of it in the ash of various fungi, he considers it a necessary element for them. Indeed, slight traces of iron are frequently present in the nutrient compounds used for the cultivation of fungi. Certain writers admit that iron produces a beneficial effect, but deny that it is absolutely necessary. However, Molisch's observation that in fungi iron can not be replaced by nickel, cobalt, manganese, or zinc deserves special consideration. Traces of zinc and related salts will, according to Raulin, Ono, and Richards, also increase the fungus mass in a given time. Richards has shown that the nutrients are more economically disposed of under this influence. It may also be mentioned here that Gautier and Drouin observed that ferric oxid promotes the fixation of atmospheric nitrogen by soil bacteria.[b]

MANGANESE IN PLANTS.

Physiologically manganese can not replace iron in plants. Plants have been raised to perfection, moreover, in culture solutions which contained no trace of manganese. However, the ash of plants, especially of woody ones, sometimes contains even more manganese than iron. Schroeder calculated for 1 hectare of 80-year-old beech trees near Tharand a content of 104.1 kilos of Mn_3O_4, but only a content of 7.92 kilos of Fe_2O_3.[c] The ash of *Pinus strobus* showed a content of 2.06 per cent Mn_3O_4, and that of *Populus tremula* 1.06 per cent Mn_3O_4 (Weber). In the case of pines even the pollen grains contain manganese. Ramann found in them 5.23 per cent ash, and in 100 parts of this ash 1.95 per cent ferric oxid and 1.12 per cent manganic oxid (Mn_3O_4).[d]

Recent investigations by the author in conjunction with Messrs. Aso and Sawa show that soluble manganese compounds may on the one

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[a] Sitzungsber. d. Wien. Akad., 1892, Vol. CIII. Aso found nearly 5 per cent ferric oxid in the ash of the spores of *Aspergillus oryzæ*.

[b] Bot. Jahresber., 1888, p. 29.

[c] Wolff's Aschen Analysen, Vol. II.

[d] The manganese content in oxidizing enzymes has been mentioned on p. 12. Aso has observed manganese in a nucleoproteid of the tea leaf (Bull. College of Agriculture, Tokyo, Vol. IV, No. 4), and Balland in the nucleins of trunks of certain trees (Compt. Rend., 1901).

hand be injurious to the chlorophyll, while on the other hand they may exert a beneficial action by stimulating growth of the plant. When these compounds are supplied in a sufficiently high degree of dilution only the beneficial action is exerted. This may be of some practical value on soils where manganese in readily available condition is wanting.

Nagaoka has recently observed in a field experiment with rice an increase of one-third of the harvest after adding manganous sulphate to the soil at the rate of 50 kilos per hectare.

THE PHYSIOLOGICAL RÔLE OF HALOGEN COMPOUNDS.

PLANTS RAISED WITHOUT CHLORIDS.

The chlorin compounds to be considered in this connection are essentially those of sodium and potassium.[a] These chlorids are not necessary in the physiological functions of lower organisms. Fungi and fresh-water algæ can be successfully cultivated without a trace of a chlorid. In the case of the higher plants, Knop and Batalin successfully cultivated even halophytes in the absence of sodium chlorid, and Knop[b] maintains that chlorids are superfluous for all plants, and hence recommends a culture fluid free from chlorids.[c] On the other hand, functions appear, in certain plants at least, which perhaps by adaptation become dependent upon the presence of chlorin, especially in the form of potassium chlorid.

VALUE OF POTASSIUM CHLORID FOR BUCKWHEAT.

Nobbe has observed that buckwheat plants thrive normally in culture solutions without chlorids until the flowering period is over, but that soon thereafter the tips of the stalks die off; the upper part of the stalk thickens and shows ring-like swellings; the epidermis bursts vertically; the dark green leaves become brittle, spotted, and puffy, and roll in; no fruit is produced, and a microscopical examination shows a great accumulation of starch granules in parts of the stems. These observations have been confirmed by Leydhecker.[d]

It might be supposed that the formation of diastase is prevented by the absence of chlorids, and that the transportation of starch thus becomes impossible, but the difficulty interposed by this hypothesis is

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[a] Calcium and magnesium chlorid have an injurious effect on plants, probably on account of the liberation of hydrochloric acid in cells, this not being assimilated like nitric or sulphuric acids, and therefore accumulating to a noxious degree.

[b] Kreislauf des Stoffs, Vol. I, p. 616.

[c] In Knop's culture fluid the proportion of the mineral nutrients is as follows: 1 KNO_3, 1 KH_2PO_4, 1 $MgSO_4$, and 4 $Ca(NO_3)_2$. The iron is suspended as ferric phosphate.

[d] Landw. Vers. Stat., 1865 and 1866, Vols. VII and VIII.

that the development of the plant proceeds normally for a considerable length of time, that is, until the flowering stage is reached. This also militates against Detmer's belief that the beneficial action of potassium chlorid on the migration of starch is due to the formation of hydrochloric acid from this chlorid,[a] which acid, in very small quantities, he claims, will promote the saccharification of starch by diastase.

According to Chittenden and to Wachsman diastase acts more energetically in the presence of small doses of sodium chlorid (0.24 per cent) than in their absence, while A. Mayer failed to observe a similar effect with potassium chlorid, which in a dose of 1 per cent retarded even diastatic action.

BENEFICIAL AND INJURIOUS ACTION OF CHLORIDS.

Observations of Sprengel, Liebig, and others show that small quantities of common salt act beneficially on various crops, especially on beans (Sprengel). Blomeyer[b] observed a very favorable effect with beans on applying even as much as 100 kilos of sodium chlorid per hectare on a soil that had received barnyard manure. But he would not give a general recommendation, since in dry climates the result might be different from that in moist climates or rainy seasons. Pethybridge[c] observed the production of a deep green color with wheat that had received some sodium chlorid. Ennenbach[d] reports a beneficial action on various plants grown in mineral solutions containing 0.15 per cent of sodium chlorid, while even 0.3 per cent exerted a retarding effect, although a stimulant action on the growth of root hairs was still observable. The author has also confirmed the observation of Nobbe that a chlorid is necessary for buckwheat in the production of ripe seeds.[e]

It is further claimed that sodium chlorid in the cotton plant augments its resistance to drought and rust fungi, and also that it toughens wheat straw; further that the transformation of starch into cellulose is facilitated.

When the amount of sodium chlorid reaches a certain concentration in the soil, injurious effects will be observed. The assimilation process in the leaves is retarded (Schimper) in the first place. Sodium chlorid also reduces the amount of chlorophyll in plants of the seacoast region, but causes the leaves to increase in thickness. The intensity of assimilation of carbonic acid is less in plants on the seacoast than in such plants growing farther inland (Griffon).

Further injurious effects are the decrease of cane sugar in the sugar

[a] Pflanzenphysiol. Unters. über Fermentbildung, Jena, 1884.

[b] Die Cultur der Landwirtschaftlichen Nutzpflanzen, Vol. I, p. 330.

[c] Botan. Centralbl., 1901, No. 33.

[d] Landw. Jahrb., vol. 30, Suppl. III, p. 21 (1902).

[e] Compare also the valuable discussion of Adolf Mayer on this question, Journ. f. Landwirtschaft., vol. 49, pp. 42 and 57.

beet and that of starch in the potato.[a] Potassium and magnesium chlorids also depress the starch content of the potato, probably on account of an increased amount of water being taken up. Potassium sulphate, being less absorbed by the tubers, has no such action.[b]

Observations, not strictly relating to chlorids alone, are the following: A solution of 1.8 per cent sodium chlorid will prevent the germination of wheat (Coupin). Certain algæ, such as *Spirogyra crassa*, will suffer in culture solutions containing 0.5 per cent potassium or sodium chlorid, while lower kinds are not affected by 1 per cent chlorid of sodium, or even more, and certain bacteria and small yeasts may grow even in the presence of from 10 to 12 per cent.

ABSORPTION OF CHLORIDS BY AQUATIC PLANTS.

The considerable absorptive power of many aquatic plants for chlorids is interesting. The ash of *Nymphæa alba*, amounting to 7 to 10 per cent of the dry matter, was found to contain 9 to 23 per cent of chlorin and that of *Spirogyra nitida* 24 per cent. The ash of such plants does not always show a sufficient potassium content to bind all the chlorin present; hence a part of the latter will in such cases be present as sodium chlorid. In order to estimate the absorptive power of *Elodea canadensis*, the writer has determined the amount of chlorin in water which ran slowly through a basin in which this plant was cultivated, and found that the water contained, per liter, 4.5 mgr. chlorin. The amount of ash in the plant was found to be 8.04 per cent, in which was 0.6 part chlorin; hence the plant contained in the dry matter over one thousand times as much chlorin as an equal weight of the water in which it was grown.

SODIUM CHLORID IN ANIMALS.

Chlorin, in the form of sodium chlorid, plays an important rôle in animals, the formation of normal gastric juice, containing 0.2 per cent hydrochloric acid, being impossible in its absence. An idea of its great importance for the blood may be inferred from the fact that on an average about one-half of the blood ash consists of chlorid of sodium. Nearly one-third of the ash of the white of hens' eggs is made up of it. This salt can not be replaced by potassium chlorid, as the latter in the same quantity would exert a noxious influence on the animal. It facilitates the absorption of protein in the animal organism and increases metabolism. An adult human body contains about 200 grams of sodium chlorid.

FLUORIDS IN PHYSIOLOGICAL RELATIONS.

The presence of calcium fluorid in teeth and bones was known long ago. Niolès [1856] observed fluorin compounds also in various other

[a] The injury to the burning qualities of tobacco should also be mentioned.

[b] Sjollema, Journ. f. Landwirtschaft., vol. 47, p. 305.

organs: Horsford, in the brain of men; Tammann [1888], in the brain of the calf, in milk and blood, and in egg albumen (about 1 mgr. fluorin in 100 parts of these objects). Jodlbauer observed fluorin compounds also in embryos. Hence the general presence of fluorin compounds in plants must be inferred. The plants probably absorb it from particles of apatite, a fluorin mineral of wide occurrence.

Sodium fluorid exerts a highly poisonous action on animals and plants; 0.15 gram per kilo body weight of an animal forms the lethal dose and Phanerogams are killed by a 0.1 per mille solution. Algæ, yeast, and bacteria are also very sensitive toward it. Still more poisonous is the silicofluorid of sodium.

In exceedingly high dilution, however, fluorids act as stimulants to fungi (Ono), as well as on phanerogams (Aso). Solutions of 0.001 per mille or 150–500 grams per hectare show a very marked stimulant effect on agricultural crops.

BEHAVIOR OF PLANTS TO POTASSIUM BROMID.

Bromine compounds occur normally in seaweeds, but as yet it is not known whether they are present only as organic or also as inorganic combinations. The physiological substitution of potassium bromid for potassium chlorid in the higher plants is impossible. In the case of buckwheat plants cultivated with potassium bromid, the writer observed long ago that only one of six lived to bear a single seed, the others dying at or near the flowering stage; hence the recent assertion that bromids are not noxious for phanerogams can be admitted only in the case of certain plants or for a limited period of development.

RELATIONS OF ORGANISMS TO IODIN COMPOUNDS.

Since the discovery that an iodin compound occurs in the thyroid and the thymus glands and also in the blood of animals, it must inevitably be assumed that traces of iodin compounds must exist in soils and plants also. Gautier[a] has demonstrated that there are traces of iodin in the air of Paris. He determined also the amount of iodin in sea water to be 2.32 mgr. per liter. Various marine organisms contain moderately large quantities of iodin. For instance, Harnack isolated iodospongin containing on an average 8.2 per cent iodin from marine sponges. Drechsel[b] found in a protein, viz, the axial horny skeleton of the coral *Gorgonia carolinii*, 7.7 per cent iodin. On decomposition with baryta this protein yields a compound of the composition of monoiod-amido-butyric acid.

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[a] According to Gautier (1899), marine algæ contain in 100 grams dry matter 60 mgr. iodin, while fresh-water algæ contain only 0.25 to 2.40 mgr. Dafert and Halla recently discovered iodin in Chile saltpeter. The iodin content of phosphorite also is of some interest.

[b] Zeitschr. f. Biologie, 1895, Vol. XV. Drechsel calls this protein "gorgonin." On decomposition it yielded not only iodin, but also 2 per cent chlorin (or bromin?).

Potassium or sodium iodid, even in small doses, exerts a poisonous influence on animals as well as on plants. Germinating buckwheat seeds placed in a full mineral solution in which the potassium was offered as iodid, died before the first leaf was developed, as the writer observed many years ago. The poisonous action of the iodid of potassium is no doubt due to the liberation of iodin by oxidation favored by the acid cell sap. Lower organisms without acid juices are rather indifferent in this respect. The writer found certain algæ and infusoria alive in culture water five weeks after 0.5 per cent of iodid of potassium had been added to it. On the other hand, 0.2 per cent potassium iodid killed larger kinds of *Spirogyra* within a few days when the culture solution contained traces of the acid monopotassium phosphate. Lower fungi and bacteria are not injured in neutral culture solutions to which even 1 per cent of this iodid is added. Potassium iodid has been found by bacteriologists to possess a germicidal action only when present in large doses. In very small doses of 25 to 300 grams per hectare iodids stimulate growth and increase the harvest.

THE PHYSIOLOGICAL RÔLE OF ALKALI SALTS.

IMPORTANCE OF POTASSIUM FOR THE FORMATION OF STARCH AND PROTEIN.

The paramount importance of potassium salts for every living cell is firmly established. In green plants they are concerned not only in the synthesis of carbohydrates, but also in that of the protein bodies, since not only is there an increase of potassium salts in such parts of green plants as are developing rapidly and consequently forming large amounts of protein, but most fungi, even in the presence of such a favorable nutrient as sugar, are found to require potassium salts for the production of protein. These salts can never be replaced by lithium[a] or sodium salts, but in certain fungi they may be replaced to a limited extent by rubidium or cæsium salts.

It is a well-known fact that plants cultivated in the presence of more sodium than potassium salts will nevertheless absorb a greater quantity of the latter than of the former. The amount of potash annually required per hectare of pine forest is about 7.5 kilos, of wheat field 37.5 kilos, of clover field 102 kilos, and of potato field 125 kilos. Other things being equal, an increase of potash will increase to a certain degree the percentage of carbohydrates, e. g., starch and sugar, and, further, potash is reported to be present in larger proportions in those parts in which the carbohydrates are transported, as in the parenchyma of the bark and pith.

[a] Although lithium salts exert a noxious action on phanerogams they do not readily affect algæ. Spirogyra still appeared normal after four weeks in a complete culture solution to which 0.3 per mille lithium chlorid was added. At a higher concentration, however, the result may be different.

Secondary potassium phosphate possibly forms loose combinations with proteins more easily than does sodium phosphate, since an increase of potassium phosphate is generally accompanied by an increase of proteins, as in the seeds. Pollen grains also seem to be rich in this salt; at least Ramann found that of the ash in the pine pollen 50.74 per cent was potash and 30.08 per cent phosphoric acid. Seeds always contain much more potassium phosphate than sodium phosphate, while on the other hand the proportion of soda to potash in form of other salts than phosphates is often found to be larger in the leaves and roots.[a]

The following table shows the composition of seeds of Gramineæ and Leguminosæ, the latter containing, as is known, relatively more protein than the former:

Analysis of the seeds of Gramineæ and Leguminosæ.[a]

Product analyzed.	Number of analyses.	Total ash. Average.	Average in 100 parts of ash.		Protein.
			Soda.	Potash.	
Gramineæ:		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Wheat	98	1.97	2.25	31.16	11.0
Rye	20	2.09	1.70	31.47	10.3
Barley	50	2.60	2.53	20.15	10.1
Maize	9	1.51	1.83	27.93	10.0
Oats	23	3.14	2.34	16.32	9.8
Millet	3	3.43	1.30	11.39	....
Average	....	2.457	1.99	23.07	10.2
Leguminosæ:					
Vetch	3	3.10	7.86	30.14	27.9
Pea	29	2.73	0.96	41.79	22.7
Lupin	3	3.95	0.37	29.84	35.3
Soy bean	1	2.83	1.08	47.00	33.2
Field bean (*Vicia*)	15	3.57	1.34	42.49	24.8
Garden bean (*Phaseolus*)	13	3.22	1.49	44.01	24.3
Average	....	3.23	2.17	39.21	29.0

[a] These figures were taken from E. Wolff's Aschen Analysen, Vol. 1.

Calculating from the above data the amount of soda and potash for 1,000 parts of dry organic matter, the seeds of Gramineæ contain 0.48 part soda and 5.67 parts potash, while those of Leguminosæ contain 0.70 part soda and 12.66 parts potash. It is seen, therefore, that on an average there is more potash in seeds which are richer in protein, but the ratios in the various cases do not show a close relation. For the Gramineæ the average proportion of potash to protein would be as 1

[a] In some cases the amount of soda found in the leaves exceeds even that of potash. Wolff's tables give for the leaf of *Daucus carota* a total ash content of 13.53 per cent for the dry matter, and for 100 parts of this ash 19.83 parts soda, but only 11.26 parts of potash. The occasionally rather large soda content in the leaves is due to the current of transpiration, containing sodium salts among other things.

to 17 and for the Leguminosæ as 1 to 23. Hornberger's investigations[a] on the growth of maize showed the relation between potash[b] and protein nitrogen in the different periods of plant development to be for the leaves 1–1.1 to 1–1.8, or calculating from the protein itself, 1–6.8 to 1–12.2.

BENEFICIAL ACTION OF SODIUM SALTS UPON PLANTS.

The fact that many kinds of plants have been raised to perfection in the absence of sodium salts proves that the latter have no indispensable function to perform in plant life. Stahl-Schroeder[c] recently inferred from his experiments what others also had already observed, that is, that sodium can not perform the special part of the functions of potassium which relates to the formation of organic substances in plants. Nevertheless, sodium salts may sometimes exert a beneficial action, and several observers ascribe to them a promoting actionin the ripening process of the Gramineæ. It is claimed that sodium nitrate yields up its nitrogen to the plant much more readily than does potassium nitrate.

Wagner and Wolff have each reported favorably on the application of sodium salts, pointing out that as regards osmotic and neutralizing functions a replacement of potassium by sodium compounds is quite possible, which is of practical value, since the sodium salts are much cheaper than the potassium salts. In a recent article Dassonville[d] pointed out the beneficial action of sodium salts upon wheat. However, further control experiments along this line will be necessary.[e]

NECESSITY OF SODIUM SALTS FOR ANIMALS.

The great amount of sodium chlorid in the blood has already been mentioned, but the blood contains still other sodium salts of importance, such as sodium bicarbonate (in the ash of ox blood was found 14 to 18 per cent sodium carbonate) and the secondary sodium phosphate. Both these salts have an important bearing on the respiration process, as they carry in solution to the lungs for exhalation the carbonic acid produced by even the most remote cells of the body. According to Bunge, cartilage is especially rich in sodium compounds.

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[a] Landw. Jahrb., Vol. XI, p. 461.

[b] Fertilizing with potassium salts does not always increase the yield of grain. Frequently it is only the yield of straw that is increased. The form in which the potassium salts are given exerts much influence.

[c] Jour. f. Landw., Vol. XLVII, p. 78.

[d] Revue Générale de Botanique, 1898, Vol. X. He states also that "potassium silicate produces a dark-green color."

[e] Copeland found that in plants potassium salts produce a greater turgor than do sodium salts. McKenney observed with luminous bacteria that either sodium or magnesium is required for light production. Potassium, ammonium, lithium, rubidium, calcium, barium, and strontium can not replace sodium (or magnesium).

CAN POTASSIUM SALTS BE REPLACED BY RUBIDIUM SALTS IN GREEN PLANTS AND IN ANIMALS?

Various authors have shown that potassium can not be replaced in plants by sodium or by lithium, starvation phenomena occurring with the former and toxic phenomena developing with the latter (Nobbe). As regards their atomic weight, sodium and lithium stand below while rubidium and cæsium stand above potassium, as follows:

$$\left.\begin{array}{l} Li = 7 \\ Na = 23 \end{array}\right\} \text{diff.: } 16$$

$$K = 39 \quad \text{diff.: } 16$$

$$Rb = 85.4 \quad \text{diff.: } 16\times3-1.6$$

$$Cs = 133 \quad \text{diff.: } 16\times3-0.4$$

Since the properties of elements are to a certain extent functions of their atomic weight, it might be supposed that the physiological capabilities of the alkali metals would increase with their atomic weight, but the facts observed are not in accord with this view.

Molisch has demonstrated that algæ can not develop if the potassium salts of the culture solution are replaced by rubidium salts.[a] In animals, also, neither cæsium nor rubidium salts can take the place of potassium salts, although a moderate amount of the rubidium salts is not noxious, and in large quantities they are even less injurious than the potassium salts.[b]

Birner and Lukanus[c] demonstrated that plants soon perish when the culture solutions contain rubidium or cæsium nitrate in place of potassium nitrate. In experiments with buckwheat plants the writer afterwards confirmed this conclusion as regards rubidium nitrate,[d] not taking cæsium salts into consideration; but he observed in addition that the action of rubidium chlorid differed to some extent from that caused by rubidium nitrate. Where the chlorid was offered the plants attained a greater height than with the nitrate. Those with rubidium nitrate died before the flowers were formed, while those with rubidium chlorid died after that period. Torsion and thickening of the stalk and curling and rolling up of the leaves were the most striking results with rubidium nitrate. In both cases, however, a diagnosis of the pathologic characters revealed essentially a disturbance in the functions of the chlorophyll bodies and in the transportation of starch, the effect on the latter being more marked with the nitrate than with the chlorid. A chemical comparison of buckwheat plants grown with potassium chlorid and of those grown with rubidium chlorid showed (1) that the

[a] On the other hand no injurious influence upon algæ is noticed when to the complete culture solutions 0.3 per mille of the chlorids of rubidium or cæsium is added.

[b] According to Richet, the lethal minimum dose of rubidium in form of rubidium chlorid is 1 gram for 1 kilo body weight when applied subcutaneously. This is about twice as much as the lethal dose of potassium chlorid.

[c] Landw. Vers. Stat., Vol. VII, p. 363.

[d] Landw. Vers. Stat., Vol. XXI, p. 389.

ethereal extract of the "potassium plants" was of a normal pure green, while that of the "rubidium plants" was of a yellowish green; (2) that the rubidium plants contained 7.8 per cent of glucose in the dry matter, while the potassium plants contained none; (3) that there was more starch in the potassium plants than in the rubidium plants.

The writer has observed further that the replacement of even one-half of the potassium chlorid in a culture solution by rubidium chlorid will impede the development, the plants reaching after six weeks only half the size of the control plants. Moreover, the leaves were partially rolled in, the flowers were scanty, and the plants died before the seeds ripened.

These experiments proved that it is impossible to raise normal seed-bearing buckwheat plants when the chlorid of potassium in the culture solution is replaced by chlorid of rubidium, but on the other hand they left hardly any doubt that rubidium chlorid can serve for certain physiological functions of which sodium chlorid is utterly incapable. With rubidium chlorid, buckwheat plants may reach a dry weight of even thirty-three times that of the seeds, but with sodium chlorid they seldom reach over five times. In a normally raised plant, however, the dry matter may be over six hundred times the weight of the seed. In the experiment with rubidium chlorid starch was formed by assimilation, but in those with sodium chlorid none was formed. The flowering stage was reached in the former case, but not in the latter. With rubidium chlorid pathologic phenomena made their appearance chiefly after the flowering stage, but with sodium chlorid starvation phenomena were observed very much earlier.

Recent experiments of the writer have proved that rubidium chlorid exerts a powerful stimulating action on the growth of plants when added in doses of 10 to 200 milligrams to 1 kilo of soil in which all mineral nutrients are present. Ten milligrams sufficed to show this effect with *Brassica chinensis*, while 200 milligrams had a surprising effect with barley. A loamy soil was manured per kilo with 1.5 grams ammonium sulphate, 0.5 gram sodium nitrate, 1.5 grams calcium superphosphate, 0.5 gram monopotassium phosphate, and 1 gram potassium carbonate. In the one case were added 200 milligrams rubidium chlorid; in the other an equivalent amount of sodium chlorid (control case). Fife barley plants, cut soon after the flowering stage, yielded the following result, the rubidium plants being normal in every regard:

Result of experiments with Fife barley plants.

Part of plant.	Rubidium plants.	Control plants.
	Grams.	*Grams.*
Ears (fresh weight)	6.1	3.7
Living leaves and stalks (fresh)	87.3	53.6
Dead leaves (air dry)	5.2	4.8

BEHAVIOR OF FUNGI TOWARD RUBIDIUM SALTS.

It has long been observed that mold fungi thrive in the presence of even very small quantities of potassium salts, traces of which are sometimes contained as impurities in certain organic compounds. These traces have to be considered in preparing culture solutions for special purposes. Yeast requires a larger amount of potassium, especially in the form of the primary and secondary phosphate, than do mold fungi. Certain kinds of microbes, such as *Anthrax* bacilli, do not develop well when the amount of potassium salts is very small. Sodium salts can not replace potassium salts even for these simple organisms, but rubidium salts can do so in certain cases, as in *Bacillus coli*, less successfully in *B. pyocyaneus*,[a] and still less in *Cladothrix*.[b] The writer has also established the fact that a mold fungus (*Penicillium*) and yeast can utilize rubidium and cæsium salts when the composition of the nourishing solution is otherwise very favorable and contains sugar and peptone. Günther's observation that the behavior of different mold fungi to rubidium salts varies is interesting, these salts being utilized by *Botrytis cinerea*, but not by *Rhizopus nigricans*.[c] The less favorable the organic nutrient is, however, the more will potassium show its superiority over rubidium. The cultures of *Cladothrix* and of *Penicillium* form floating masses in the solution containing potassium salts,[d] while they gradually sink to the bottom in those containing rubidium salts. Further, spore formation is almost entirely prevented in *Penicillium* when rubidium is offered in place of potassium. Only after an increase of the magnesium sulphate a scanty formation of spores was noticed.

The secondary and primary phosphates are the most favorable forms in which to offer potassium salts to fungi. In case phosphoric acid is applied as an ammonium salt, potassium may be added as lactate or tartrate or as other assimilable organic salts.

Finally, it may be mentioned that of all the alkali salts potassium salts exert the most powerful positive chemotaxis upon bacteria, and that next to them come rubidium salts (Pfeffer).

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[a] Bot. Centralbl., 1898, No. 26.

[b] Winogradzki has shown that *Mycoderma vini* also can utilize rubidium salts to advantage, but not cæsium salts.

[c] Dissertation, Erlangen, 1897.

[d] The writer prepared the culture solutions with the purest materials, consisting in this case of—

	Per cent.
Sodium acetate	0.5
Glucose	1.0
Di-ammonium phosphate	.1
Magnesium sulphate	.02
Potassium tartrate	.10

PHYSIOLOGICAL SUPERIORITY OF POTASSIUM SALTS.

The question to what peculiar property of potassium its physiological capacity must be ascribed implies also the questions: Why can the physiological functions of potassium salts not be performed by the related sodium salts? In reviewing all the properties of the two metals and of their compounds can not such chemical differences be discovered as would also explain the great physiological difference? Can there not be found in potassium chemical properties that give it a certain superiority over sodium? Long ago the writer searched for striking and characteristic differences and believes he is justified in calling attention to the following facts, which prove that potassium and its oxid can bring on in certain cases a so-called chemical condensation which sodium and its oxid can not. For instance, carbonic oxid can be condensed by potassium to triquinoyl, a benzene derivative, but not by sodium (Lerch, Nietzki). Phenol added to fusing potassium hydroxid will, under condensation, yield diphenol among other things, while with sodium hydroxid, oxidation, and but little condensation, is observed, resorcin and phloroglucin resulting (Barth).

Among other noticeable differences may be mentioned, (1) that certain potassium salts condense ethyl aldehyde to aldol, while sodium salts change it to croton aldehyde (Kopp and Michael); (2) that potassium acts on boiling triphenyl methane, resulting in the development of hydrogen, but that sodium does not; (3) that potassium salicylate is converted at 210° C. into the isomeric paraoxybenzoate,[a] while in the sodium paraoxybenzoate just the reverse transformation is produced at 300° C. (Kolbe); (4) that potassium hydroxid decomposes peroxid of hydrogen more quickly than does sodium hydroxid (Schöne).

It seems very probable to the writer that from the physiological point of view the condensing properties of potassium are of prime importance. Substantial reasons exist for assuming chemical condensation processes, not only in the formation of carbohydrates and fat, but also in that of the proteins, i. e., in the three principal compounds of the plant cell. The writer called attention to this probable rôle of potassium salts in plants as early as 1880,[b] and still holds this explanation to be the correct one.

It is very probable that for the condensing operations the organoids of plant cells use a potassium-protein compound. It is well known, of course, that chloroplasts require potassium salts for the assimilatory function and further that they have an alkaline reaction.[c] Finally,

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[a] The corresponding rubidium salt in this case behaves similarly and therefore bears more resemblance to the potassium than to the sodium salt.

[b] Pflüger's Arch., Vol. XXII, p. 510.

[c] Molisch (Bot. Zeit., 1898, No. 2) observed that as soon as the cells are killed and the chloroplasts come in direct contact with the acid cell sap the cells of *Coleus* or *Perilla*, rich in chloroplasts and containing anthocyan in an acid cell sap, underwent the characteristic change from red to blue and green produced by alkaline substances. Cells of the same plants which are poor in chloroplasts or free from them do not show this change.

there can be no longer any doubt that sugars are produced by condensation. As regards the formation of protein, the writer has on various occasions pointed out that certain facts, especially the great rapidity of protein formation in many instances and the absence of by-products and between-products, inevitably lead to the assumption that in this process also condensation plays an important part.

But potassium salts are absolutely indispensable in animal life also, although the synthetic work performed is not so far-reaching as in plants. However, the formation of fats from sugar in the animal body requires condensation as well as reduction, while the formation of glycogen[a] from glucose and that of proteids from proteoses consists in dehydration and polymerization. In such cases potassium salts may play a rôle, and perhaps also in the processes of organization, as, for example, in the leucocytes and gland cells, which latter are in certain cases frequently renewed, or in the contractile substance of the muscles when work or starvation have destroyed a part of it.[b]

Nägeli ascribed the differences in the physiological capacities of potassium and sodium salts to their different affinities for water. Sodium salts bind water of crystallization, but corresponding potassium salts do not, and thus being free from such a dense sphere of water the latter are better qualified for catalytic work. The dense layer of water around the molecules of sodium salts would not only prevent the salt itself from coming into immediate contact with other molecules, but it also would impede an effectual transmission of vibrations. On this basis also Nägeli tries to explain the fact that the soil absorbs potassium salts better than it does sodium salts, claiming that the latter are prevented by their water mantle from following the attracting forces.[c] However, objections can be easily raised to this view, the most serious one being that by no means has every sodium salt the water of crystallization.

THE PHYSIOLOGICAL RÔLE OF CALCIUM AND MAGNESIUM SALTS.

DISTRIBUTION OF LIME AND MAGNESIA IN PLANTS.

It has long been known that calcium and magnesium salts can not physiologically replace each other, and the question as to the functions of these salts has until recently been a matter of conjecture. The striking regularity with which the leaves of plants show a relative

[a] The liver, which is the principal organ in glycogen formation, contains, according to Oidtmann, three times more potassium than sodium, while in the spleen the proportion is, according to the same author, just the reverse.

[b] Organization, as it takes place in a developing organ, is one of the least-known vital processes. One thing, however, is sure, that is, that a connection of numerous protein molecules in groups of a higher order takes place. This connecting process was supposed by Pflüger to consist in polymerization or etherification.

[c] Sitzungsber. d. Bayr. Akad. Wiss., 1879, p. 348.

increase in lime, while the seeds show an increase in magnesia, has finally furnished a clew to the mystery of the action of these salts. A number of cases will serve to illustrate that different parts of the same plant contain quite different proportions of lime and magnesia. Let us first consider the leaves of the Gramineæ, since in them the absence of calcium oxalate excludes an otherwise misleading factor. The following data are extracted from tables in Liebig's work:[a]

Per cents of lime and magnesia in the ash of the grain and the straw of Gramineæ.

Part of plant.	Magnesia.	Lime.
Grains of—	*Per cent.*	*Per cent.*
Barley	8.29	2.48
Oats	7.70	3.70
Wheat	11.75	3.30
Maize	13.60	0.57
Rye (bran)	15.82	3.47
Straw of—		
Barley	2.97	7.28
Oats	4.58	7.29
Wheat	1.69	6.93
Maize	1.84	5.33
Rye	2.41	9.06

A better basis for a comparative estimate will be obtained if the average of these figures is taken and compared with the relative number of molecules instead of the absolute weight. The seeds of Gramineæ will then be found to contain for every 17 molecules of lime 100 molecules of magnesia, while in the straw there will be found fully 224 molecules of lime for every 100 molecules of magnesia. The leaves of *Phaseolus vulgaris* contain in comparison to the magnesia content four times as much lime as the seeds, and those of *Brassica napus* seven times as much. The proportion of magnesia to lime in tobacco leaves was found to be, on an average, as 1 to 5. The proportion of these constituents in the flowers is also different from that in the leaves. For example, in the case of *Humulus lupulus* there was found in the—

Flowers .... 1 part magnesia to 2 parts lime.
Leaves .... 1 part magnesia to 6 parts lime.

On comparing the underground parts of the plants with the leaves, it was also found that the latter contain more lime. For example, it was observed in—

Daucus carota, roots .... 1 part magnesia to 2.5 parts lime.
leaves .... 1 part magnesia to 14.0 parts lime.
Solanum tuberosum, tubers .... 1 part magnesia to 0.6 part lime.
leaves .... 1 part magnesia to 6.1 parts lime.

[a] Die Chemie in ihrer Anwendung auf Agrikultur und Physiologie, 7 ed., Part I. The analyses were made by Way and Ogsten, Weber, and others.

Very great differences are revealed also in the comparison of the wood with the seeds in this regard, the lime content being relatively increased in the wood:

Abies pectinata, seeds	1 part magnesia to 0.09 part lime.
wood	1 part magnesia to 4.62 parts lime.
Pinus sylvestris, seeds	1 part magnesia to 0.12 part lime.
wood	1 part magnesia to 1.60 parts lime.

During the fruiting year of a beech tree 150 years old, R. Weber[a] several years ago made some interesting observations on the migration of magnesia. He found that magnesia as well as nitrogen migrated from the trunk to the points of seed formation, and in a smaller measure also sulphuric and phosphoric acids did the same. The decrease of the magnesia in the wood extended to ninety annual rings. The wood of the tree was analyzed in zones of thirty rings each. The percentage of lime and magnesia in the ash are given as follows, as is also for comparison the composition of a beech tree of the same age which had grown near by, but which bore no fruits that year:

Lime and magnesia in a fruiting beech and in a control beech.

Part of tree.	Beech tree in fruit. In the ash—		Beech tree not in fruit. In the ash—	
	Lime.	Magnesia.	Lime.	Magnesia.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Bark	85.05	2.60	82.10	3.65
Zone 1	33.92	12.65	27.69	29.25
Zone 2	34.13	11.95	31.52	26.72
Zone 3	35.98	12.15	33.55	20.39
Zone 4	33.36	13.36	27.59	19.02
Zone 5 (heartwood)			31.21	11.00

As shown by the table, there was relatively a most striking decrease of magnesia to lime in zones 1, 2, and 3 of the trunk of the seed beech as compared with the corresponding zones from the control beech.

The leaves of aquatic plants are also rich in lime. The proportions of magnesia and lime were found to be, in *Nymphæa lutea*, 1:8.5; in *Lemna*, 1:3.3 to 1:7.6; and in *Elodea canadensis*, 1:8.4. Also algæ show similar proportions, as seen from the ash analyses of *Spirogyra nitida* by Pennington (1896) and of fucoids by Gödechens (1854). Algæ incrustated with calcium carbonate must, of course, be here excluded.

From what has been said under this head it will be seen that the analytical investigations of the ash of plants show (1) that lime and magnesia are present in every part of the plant, and (2) that the leaves contain relatively more lime and the seeds relatively more magnesia than the other parts of the plants. These characteristics can not be accidental, but must be the result of certain functions.

[a] Forstlich. Naturw. Zeitschr., 1892.

THE PHYSIOLOGICAL IMPORTANCE OF LIME SALTS IN PLANTS.

The greater the leaf surface developed in a given time, the more lime is necessary. A normal crop of wheat requires per hectare (nearly 2.5 acres) about 11.6 kilos; sugar beets, 30.2 kilos; grass, 49.4 kilos; clover, 111.8 kilos, and tobacco, 153.7 kilos, while a normal growth of wood needs annually about 20 kilos of lime, besides 7 to 16 kilos of magnesia, 2 to 10 kilos of potash, and 0.8 to 4 kilos of phosphoric acid. When the large demand by plants for lime salts is taken into consideration, it is easily understood that an absence or deficiency of lime becomes apparent very early.

Stohmann[a] kept maize shoots alive for some time in a culture solution free from lime, but all development gradually ceased with the consumption of the stored-up lime. However, when at the end of several weeks some calcium nitrate was added, a very striking effect was noticed, hardly five hours elapsing before new buds pushed out from the sickly looking tips.

Heiden[b] observed that maize and peas in culture solutions without lime lived only four weeks, and reached respectively only 18.9 and 27 cm. in height. In culture solutions without magnesia, however, maize lived ten to twelve weeks and peas lived eight weeks and attained a height of 44 and 30 cm. respectively. In solutions without potassa or phosphoric acid, but otherwise complete, such plants lived from eight to twelve weeks. The absence of lime, therefore, was felt first, owing probably to the relatively small amount of lime in the reserve store of the seeds..

Palladin[c] placed etiolated leaves of *Vicia faba* on the surface of distilled water, on a 10 per cent cane-sugar solution, and on solutions of 0.3 per cent calcium nitrate with and without the addition of cane sugar, but a noticeable growth was observed only where both sugar and calcium nitrate were present. The same author[d] has found that etiolated leaves of *Vicia faba* contain less lime than do green leaves. His analysis showed that there were contained in 1,000 parts of green leaves 13.3 parts of lime, but in 1,000 parts of etiolated leaves only 2.6 parts of lime. The former yielded 10.3 per cent of ash, the latter 7.54 per cent. Stoklasa found in diseased leaves of the sugar beet less than half the amount of lime present in healthy leaves of this plant.

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[a] Ann. Chem. Pharm., Vol. CXXI.

[b] Centralbl. f. Agr. Chem., Vol. XVII, p. 622. Prianishnikow observed that shoots develop quicker in a solution of gypsum than in distilled water, which fully accords with the writer's observations. Seedlings of *Phaseolus*, *Pisum*, and *Cucurbita* kept in distilled water die before all the reserve material is consumed. An addition of a calcium salt to the distilled water leads, however, to the perfect exhaustion of the reserve stores (Boehm, Liebenberg).

[c] Ber. d. Deut. Bot. Ges., 1891, p. 230.

[d] Ber. d. Deut. Bot. Ges., Vol. X, p. 179.

Church's investigations[a] with albino leaves demonstrated that the composition of their ash is very different from the ash of healthy leaves, as the potassa is considerably increased in the white leaves, while on the contrary the lime is more abundant in the green leaves. It is to be regretted, however, that the author did not determine separately the amount of lime present as oxalate and carbonate and that portion of the lime belonging to the organized matter itself, calculating the results for equal surfaces in both cases. It is also very characteristic that the lime content of the phanerogamic parasite Cuscuta, which forms no chloroplasts in the full-grown state, amounts to only 2 per cent in the ash, while the clover, its host, is very rich in lime.

Another interesting case, showing a decrease in lime content in diseased leaves, was observed by Dr. Erwin F. Smith in his studies of peach yellows. He gives the percentage of lime in the ash of the healthy leaves, according to analyses made by Mr. N. E. Knorr, as 40.58, and in the diseased leaves as only 23.88.[b] According to a later analysis, made by Dr. Eastwood at Dr. Smith's request, the ash content of healthy twigs of one season's growth is given as 2.10 to 2.58 per cent and that of diseased twigs as only 1.6 per cent, and of healthy twigs from another orchard as 1.4 per cent and of diseased twigs as only 1 per cent.[c] In these cases the amount of lime was also less in the diseased leaves, while potash, magnesia, and in most cases phosphoric acid also were relatively increased, as will be seen from the following table:

Analytical data from diseased and healthy trees from four orchards.

[Per cents in the ash.]

Constituent.	Orchard A, at Magnolia, Del.		Orchard B, at Dover, Del.		Orchard C, at Magnolia, Del.		Orchard D, at Still Pond, Md.	
	Healthy.	Diseased.	Healthy.	Diseased.	Healthy.	Diseased.	Healthy.	Diseased.
Calcium oxid	40.58	23.88	61.21	47.61	48.85	43.68	40.51	31.75
Magnesium oxid	4.81	5.97	5.62	7.65	3.21	4.31	2.85	10.23
Potassium oxid	15.52	31.86	15.02	20.19	28.26	32.51	30.18	30.76
Phosphoric acid	7.55	13.79	10.63	12.63	10.45	9.29	12.00	16.86

The observations which Honda and the writer[d] made with young pine trees transplanted to pure quartz sand moistened with culture solutions free from lime have shown that the new leaves reached only half their normal size, and that the young trees gradually perished.

[a] Jour. Chem. Soc., 1878 and 1886. The investigations were made with *Quercus rubra* bearing some albino branches, and also with albino leaves of *Plectogyne variegata* and of *Hedera helix*.

[b] Erwin F. Smith, Bull. No. 4, Division of Botany, U. S. Dept. of Agriculture.

[c] Erwin F. Smith, Bull. No. 4, Division of Vegetable Physiology and Pathology, U. S. Dept. of Agriculture.

[d] Bull. Coll. of Agr., Tokyo, Vol. II, No. 6.

Bokorny[a] has cultivated algæ (*Spirogyra*, *Zygnema*, and *Mesocarpus*) in culture solutions, in one of which there was no lime, in another no magnesia, and in a third neither lime nor magnesia. These culture solutions were kept in aluminum vessels to avoid any trace of substances derived from glass. In the complete solution a normal formation in every respect was noticed. In the solution in which lime was absent the first phenomenon to occur was a decrease of the chloroplast, the chlorophyll band of *Spirogyra* diminishing not only in breadth and thickness, but also in length, and the original spiral finally becoming a straight line parallel to the longer axis. Some starch, however, was still produced, which proves that it is not the lack of organic matter and of potash which here brings on this shrinkage, and that the result can be attributed only to the absence of lime. In the solutions in which magnesia and lime magnesia alone were absent the volume of the nucleus decreased considerably, as well as that of the chlorophyll bodies. The writer has repeatedly observed that *Spirogyra majuscula* collected from swamps containing only traces of lime had very slender chlorophyll bands and scarcely any starch, but that they contained much stored-up albumin. When placed in culture solutions containing a moderate amount of lime salts the bands soon became broader.

Rudolph Weber[b] instituted a series of experiments with cultures of peas under glass of different colors, and compared these plants with plants grown in very faint light and with normal control plants. The plants were grown in purified quartz sand and watered with culture solutions in equal quantities. The culture was terminated after forty-four days, because the plants under violet and green glass began at that time to show signs of approaching death. The analyses of the ash gave some interesting results, especially as regards the lime content, and are as follows:

Comparative amounts of magnesia, lime, and potash per thousand parts of dry matter of normal and etiolated plants and plants grown under different colored glass.

Condition of plant.	Magnesia.	Lime.	Potassa.
	Per cent.	*Per cent.*	*Per cent.*
Normal	10.2	32.1	48.5
Etiolated	6.7	12.4	44.9
Under green glass	8.3	18.2	56.5
Under violet glass	8.5	20.2	45.6
Under red glass	9.5	24.3	56.5
Under blue glass	8.8	30.2	61.1
Under yellow glass	9.5	30.3	53.2

[a] Bot. Centralbl., 1895, No. 14. The complete solution contained—

	Per cent.
Potassium nitrate	0.04
Potassium sulphate	.03
Monopotassium phosphate	.03
Calcium nitrate	.03
Magnesium sulphate	.03

[b] Landw. Vers. Stat., 1875, Vol. XVIII, p. 19.

The amount of phosphoric acid varied only from 16.7 to 20.5 per cent. The etiolated plants and those under green glass contained the smallest amount of lime, the beneficial rays having been cut off by the glass in the latter case.

VIEWS ON THE FUNCTIONS OF LIME SALTS.

Boehm[a] observed irregularities in the transportation of starch when lime salts were absent in the culture solutions. The plants (*Phaseolus multiflorus*) recovered[b] on the addition of calcium salts, while on the other hand the addition of magnesium salts hastened their death. The irregularity of behavior in the absence of lime consisted in the accumulation of starch in the pith and bark of the lower part of the stem. The death of the affected plants commenced generally in the upper parts of the stems and gradually spread to the lower parts. Boehm further attributed to the lime a function in the formation of the cell wall. He says: "In order to form the cell wall from starch and sugar, lime is just as important as for the formation of the bone. The lime forms the skeleton of the cell wall." One author,[c] however, claims that Boehm's inferences are not justified, as he had studied only one case. Some authors have even gone so far as to assert that lime salts are by no means required for every part of a plant, and one author concluded that leaves of *Tradescantia* may be raised without lime, another that the young wood is free of lime, and a third that *Fucus* may be found without a trace of lime.[d] These statements, however, were based principally on microscopical tests and could not be upheld. Some new leaves of *Tradescantia* may indeed develop completely when the branches are kept in distilled water, since, as the writer has observed, the nodes contain a considerable amount of stored-up lime. As to the assertion in regard to young wood, Weber's analyses[e] have revealed a considerable amount of lime in its ash. For example, 1 cubic meter (Festmeter) of the wood of *Larix* was found to contain 700 grams of lime, of which 112.4 grams belonged to the young wood. The young wood of *Fagus* contained about 29 per cent of lime in the ash. As regards the *Fucus* referred to above, it was only its cell sap that proved to be free from lime, while an examination of the organized parts revealed lime in them.

[a] Ber. Akad. d. Wiss., Wien, 1875.

[b] The addition of calcium chlorid, however, did not prevent death, probably owing to the liberation of hydrochloric acid when the attempt is made by the plant to assimilate the lime from this salt.

[c] Liebenberg, Ber. Akad. d. Wiss., Wien, 1881. Cf. also Déherain and Demoussy, Compt. Rend., 1901, vol. 132, p. 523.

[d] Boehm's hypothesis was entirely misconstrued by one author, who believed he had refuted it by showing that the migrating sugar is not bound to lime—a fact that might have been foreseen, as such a compound would be decomposed quickly by carbonic acid.

[e] Forstlich. Naturw. Zeitschr., 1892, p. 6, and 1893, p. 215.

Thus far the only plants which have been proved positively to develop without lime salts are lower forms of algæ and fungi.

Like Boehm, Schimper observed an abnormal accumulation of starch where there was a deficiency of lime, but he declares this to be a mere secondary pathological phenomenon, and pointed out that even leaves which are packed with starch may die. This, however, can not be regarded as a refutation of Boehm's views. In order to render starch available for respiration it must be saccharified. In Schimper's case a failure to produce diastase might adequately account for the result. Other discrepancies between the observations of several authors may have their origin in the different lime content of the seeds used for the experiment.

Rauner[a] agrees with Boehm in ascribing to the lime the function of aiding in the growth and solidification of the cell walls but he does not agree with his other views. However, his reason for believing that lime has nothing to do with the transportation of starch is not convincing. Certainly, the mere chemical process of forming starch from sugar does not require lime, but the formation of leucoplasts and chloroplasts—the indispensible apparatus for starch formation—may require it.

Holzner's view[b] that lime salts aid in the assimilation of sulphuric and phosphoric acids is very improbable, since his hypothesis would require the formation of oxalic acid in every protein producing cell—a condition which is not realized, and, moreover, the assimilation of these acids also takes place in fungi in the absence of every trace of lime salts. Finally, Hornberger[c] and others have objected to this view as not agreeing with their observations.

The functions of lime salts are believed by Schimper and others to consist in merely effecting certain processes of metabolism. Schimper[d] found that in the absence of lime the acid potassium oxalate accumulates in the leaves and buds and acts as a poison, hence calcium salts are useful, inasmuch as they precipitate the oxalic acid and thus prevent its noxious action. P. Groom[e] suggested that the injurious action of the acid potassium oxalate consists in retarding the action of diastase on starch, and thus its presence in the assimilating tissue brings about an accumulation of starch, due to the arrest of its transformation into sugar; then, as the soluble oxalate accumulates, there is also a retardation in the formation of starch, and this finally leads to the death of the protoplasm. Groom's theory, however, does not explain why calcium is required also by plants that do not form oxalic acid, hence the bad effects caused by a deficiency of lime must be explained in some other way. Although *Equisetaceæ* and most ferns

[a] Landw. Vers. Stat., 1883, Vol. XXIX, p. 271.
[b] Flora, 1867, p. 497.
[c] Landw. Jahrb., 1882, Vol. XI, p. 455.
[d] Flora, 1890, p. 209.
[e] Bot. Centralbl., 1896, No. 33.

and grasses, and even some species of the *Solanaceæ* and *Liliaceæ*, are free from calcium oxalate, they all nevertheless require lime.

Neither Schimper nor Groom have raised the question as to why oxalates, even if neutral, exert a poisonous action on chlorophyll-bearing plants, while to the writer this question appeared to be the most important in this connection.

The greater lime content of the green parts first led the writer to suppose that the chlorophyll bodies might contain calcium compounds, and on the basis of this hypothesis he inaugurated a series of investigations. Among other things, these showed that the neutral oxalates are not poisonous to the lower fungi and that the development of these is not at all retarded by adding considerable quantities of neutral potassium oxalate to the culture solutions. Beer yeast is not injured by adding even as much as 4 per cent of this salt to a fermenting mixture. As in such cases the lime would become insoluble and its assimilation would thus be frustrated, the writer has come to the conclusion that these organisms do not require lime.[a] It is otherwise in the case of the higher algæ, however. As the chlorophyll bodies of *Spirogyra* possess a highly differentiated structure, and even slight evil effects readily manifest themselves in certain changes along their margin, in the retraction of the lobes, etc., vacuolation of the chloroplasts, this alga was selected for the test. When *Spirogyra majuscula* was put into a 2 per cent solution of neutral potassium oxalate, a very striking fact was brought out, many of the chlorophyll bands being injured in even as short a time as thirty to forty minutes, while in even less time the nucleus showed a remarkable contraction, dwindling to a mere thread and thus causing a constriction of the cytoplasm where the plasma strings were attached. Moreover, filaments of *Spirogyra* which had been exposed for ten minutes to the action of this oxalate solution and had still preserved their full turgor, were incapable of repairing the injury done even after being replaced in well water rich in lime, and they died after twenty-four hours. Even five minutes' action ultimately caused death. In a weaker solution (0.5 per cent) of oxalate the nucleus does not shrink to a thread, but slowly swells up and finally becomes an irregular, scalloped figure. In a still higher dilution (0.1 per cent) the poisonous action proceeds so slowly that it requires a number of days to completely kill all the cells.

In other species of algæ, such as *Vaucheria*, *Mougeotia*, *Zygnema*, *Cosmarium*, *Œdogonium*, *Chladophora*, *Sphæroplea*, etc., death, accompanied by swelling of the chlorophyll bodies, occurred after twenty-four hours' action of a solution of 0.5 per cent. Diatoms died in this solution in fifteen hours, but in a solution of 0.05 per cent some diatoms were still alive after three days. In higher dilutions the poi-

[a] Erroneous representations and unjust remarks in regard to this point have been refuted by the writer in Bot. Centralbl., 1898, Vol. LXXIV.

sonous properties decrease rapidly.[a] Phanerogams also are easily attacked by oxalates. When placed in a 2 per cent solution of neutral potassium oxalate, the nucleus of an onion shows a contraction of about one-fifth of its normal diameter within ten to fifteen minutes. Leaves of *Elodea canadensis* and *Vallisneria spiralis* were killed completely in thirty-six hours[b] in a 1 per cent solution. The control experiments with potassium tartrate or sulphate, failed in all cases to show similar action. The claim, therefore, that lime salts are necessary to precipitate tartaric acid in plants that contain tartrates instead of oxalates has no support, since neutral tartrates are not poisonous, as are neutral oxalates.

The cytoplasm succumbs last, and its death is probably a secondary effect, due to the death of the nucleus and the chlorophyll body. Indeed, it can be easily seen that the cytoplasm dies sooner when the number of chlorophyll bodies contained in it is increased. It is on this account that the circulation of the cytoplasm lasts much longer in the root hairs of *Chara* when under the influence of a dilute solution (0.5 per cent) of potassium oxalate than it does in the cells of the internodes filled with chlorophyll bodies. An equally dilute solution of neutral potassium tartrate shows no injurious action in the same length of time. The writer's explanation of the poisonous action is as follows: Judging from the most characteristic properties of soluble oxalates, that of precipitating lime from even highly diluted solutions of lime salts and that of depriving lime compounds generally of their lime, converting it into the insoluble oxalate, he inferred from the peculiar poisonous action *the existence of calcium-protein compounds in the organized particles from which the nucleus and the chlorophyll bodies are built up.* Such organized calcium compounds would have a well-defined capacity for imbibition, which would change with the replacement of the calcium by another element, and this altered water content must lead to a disturbance in the structure, which must prove fatal if not remedied in its initial stages. A peculiarity of protoplasm is that alteration of the structure is soon followed by the chemical change from the active state of its proteids to the passive. Now, when potassium oxalate acts on the inferred calcium-protein compounds they yield in addition to calcium oxalate the corresponding potassium-protein compounds, which, on account of the different capacity for imbibition, can not physiologically replace the calcium compound. Moreover, neither tartrate nor sulphate (which act much less energetically than the oxalate on calcium compounds[c]) attacks the nucleus or the chlorophyll bodies. This also

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[a] This, however, is not the case with free oxalic acid.

[b] There are some remarkable cases in which monopotassium oxalate exists in the cell sap and still produces no injury, as, for instance, in *Rumex* and *Oxalis*. In these cases it is necessary to assume an unusual density of the tonoplasts—that is, a density sufficient to protect the nucleus and protoplasm.

[c] Calcium tartrate dissolves in about 2,000 parts of water.

shows plainly that it is impossible to accept the view that potassium oxalate becomes dissociated in the cells and that it is the free oxalic acid which, on account of its acidity, kills the nucleus, since potassium nitrate would be expected to act in just the same way.[a]

It will of course be difficult to prove microchemically the formation of calcium oxalate in the chlorophyll body or nucleus when potassium oxalate is left to act upon them, since the amount of calcium in them is naturally very small, judging from the great molecular weight of the organized proteids with which it would be combined. Moreover, the formation of distinct crystals of calcium oxalate would be impeded by the peculiar consistency of the living structures. It was claimed that in view of the highly complicated conditions in the cells the assumption of a direct connection between a working cause and an observed pathological result could not be admitted, as the latter might be simply the effect of primarily produced "disturbances of nutrition." However, this claim can not be sustained in the case of the action of neutral oxalates upon the nuclei, for in the first place this proceeds very rapidly in concentrations of over 1 per cent, and in the second place the processes of metabolism in objects like *Spirogyra* proceed very slowly.

Further observations by Migula[b] deserve to be mentioned here, as they demonstrate that free oxalic acid is among the most poisonous of organic acids. For example, in a solution of 0.004 per cent of free oxalic acid the nucleus of *Spirogyra orbicularis* was observed to swell up, frequently to six times its normal volume, and become turbid and opaque, while the cytoplasm still remained alive for some time. In stronger solutions the cells die too quickly to show such characteristic symptoms, their death in this case being due chiefly to mere acidity.

When some filaments of *Spirogyra majuscula* were placed in 500 cc. of a solution of free oxalic acid[c] in even as high dilution as 0.0001 per cent, the writer observed great injury to some of the threads after five days. In most of the cells the plasma strings were retracted, the nucleus was contracted and rolled to the cell wall, and the sinuate margins of the chlorophyll bands were swollen up and numerous little drops became

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[a] When acting on *Spirogyra* the potassium oxalate seems to pass direct to the nucleus through the plasma strings and not through the tonoplast, but, on the other hand, when potassium oxalate is contained in the cell sap of certain plants it seems to be confined there by the density of the tonoplast, which also prevents its direct contact with the nucleus in this case. In this connection Migula observed some interesting facts with *Spirogyra* kept in well water to which very small quantities of organic acids had been added. These were gradually oxidized in the cells into oxalic acid of which some was retained as neutral oxalate in the cell sap, and yielded a precipitate of calcium oxalate when placed in a diluted solution of lime salts.

[b] The Influence of Dilute Acids on Algae, Breslau, 1888.

[c] Purest water distilled from glass vessels was used for all experiments with *Spirogyra*.

visible in them.[a] A very striking feature was the long-continued persistence of turgor under these conditions, this being due to the cytoplasm remaining alive for a considerable time. In equally diluted solutions of tartaric acid most of the cells were perfectly normal after nine days, which shows that the character of acidity at this high dilution exerted merely a secondary influence and that this alone can not account for the action of the highly diluted oxalic acid.

FORMATION OF LIME INCRUSTATIONS.

It may not be out of place here to say a few words about the formation of incrustations of calcium carbonate on certain aquatic plants, especially *Chara*—a phenomenon which Pringsheim[b] tries to explain on the hypothesis that by assimilation of the dissolved carbonic acid the neutral calcium carbonate is produced from the bicarbonate. However, the fact that not every plant growing in the same water and near *Chara* shows the incrustation must lead to the assumption that either the assimilation is of much greater energy in *Chara* than in many other plants, or that the surface of this plant is especially adapted for the absorption of the neutral calcium carbonate.

Hassack[c] advanced another hypothesis, that is, that the plants secrete an alkaline carbonate, which decomposes the calcium bicarbonate. This view, however, the writer has proved to be entirely erroneous.[d] The reaction with phenol-phthalein, which Hassack used, is not due to an alkaline carbonate, but to neutral calcium carbonate in a colloidal condition. Even the warming of ordinary water rich in calcium carbonate will produce ephemerally a red color with phenol-phthalein.[e]

CAN CALCIUM IN PLANT CELLS BE REPLACED BY STRONTIUM?

It has long been recognized that calcium salts can not be replaced by potassium or sodium salts. Were it a well-founded hypothesis that calcium salts serve only for certain phases of metabolism and are not connected with more important properties of the protoplasm itself, then there might be taken a plain chemical view of the matter, that is, that the action of the bivalent elements is often different from that of the monovalent elements. Thus, for example, dextrose yields saccharin[f] when treated with lime, but not when treated with potash

[a] Considerable swelling of the nucleus took place in a solution of 0.01 per cent oxalic acid.

[b] Jahrb. f. Wiss. Bot., Vol. XIX, p. 138.

[c] Unters. aus d. Bot. Instit., Tübingen, Vol. II, pp. 469–475.

[d] Flora, 1893, No. 4.

[e] Possibly the alga produces acids which form insoluble compounds with lime, and hence the absorbed lime accumulates. By gradual oxidation of such salts calcium carbonate is produced and is then excreted.

[f] This product is not the sweet saccharin of commerce.

(Kiliani); calcium carbamate yields calcium cyanamide upon heating, while potassium carbamate yields potassium cyanate (Drechsel); barium dibromsuccinate yields monobrommaleic acid on boiling of the aqueous solution, while the sodium salt yields monobrommalic acid.

It is certainly not the bivalent character of calcium, however, that determines its physiological value, for in that case barium or strontium might fulfill the same office, which is impossible. The inability of barium to do this might be explained by the most characteristic property of soluble barium salts, which is to precipitate sulphuric acid from even high dilution of sulphates, hence in plants the assimilation of sulphur from sulphates would become an impossibility. However, it would still be difficult to explain why barium salts are poisonous for animals, and also why strontium salts can not replace calcium salts in either plants or animals.[a]

The more intimate the connection between the functions of the lime and the vital properties of the cells, the more difficulty will naturally be encountered in an endeavor to substitute strontium for calcium, and experiments made in this connection argue against the possibility of the substitution. The writer made some experiments with an alga (*Spirogyra*) in 1892 which demonstrated that although this alga can remain healthy for several weeks at the ordinary temperature in a culture solution containing strontium nitrate in place of calcium nitrate, its further growth is nevertheless impeded, and, moreover, that there is soon a noxious influence at a higher temperature (28° C.). Thus, for example, many cells died when kept at 28° C. in a solution of 0.3 per cent strontium nitrate, but this was not the case in a 0.3 per cent solution of calcium nitrate. This conclusion has been essentially confirmed by Molisch, who observed the interesting fact that in the process of cell division the cell plate is not properly formed when strontium salts are present in place of calcium salts. This occurs even when a small amount of a calcium salt is present, in which case the injurious effects of the strontium salt are not entirely prevented. The cell plate is the result of the work of the nuclear spindle, and the supposition that the cause of this defective work is attributable to a diseased condition of the nucleus seems justifiable. If the lime were not concerned in the most intimate working of the nucleus the phenemenon in question would hardly be intelligible.

Similar experiments with beans and maize were inaugurated later on by Haselhoff,[b] but he offered calcium and strontium salts together in the beginning and gradually diminished the lime in the culture solution. The plants, however, very probably made use of the occasion to store up a certain amount of lime, which they may have used

[a] Only certain enzyme actions form exceptions, as Bertrand has shown for pectase; here also barium or strontium salts cause a precipitate.

[b] Landw. Jahrb., Vol. XXII, p. 853.

in the later period, and hence his conclusion that a substitution of calcium for strontium salts is possible can not be admitted.

The writer made an experiment with a phanerogamous plant also. Branches of *Tradescantia* from 12.5 to 12.8 cm. long were placed in solutions of—

	Per cent.
(1) Calcium nitrate	0.2
(2) Strontium nitrate	.2
(3) Calcium and strontium nitrate, each	.1

At a temperature of 10–15° C. a decided difference was noticed after twelve days. In the calcium nitrate solution young rootlets 0.5 cm. in length had appeared, but in the strontium nitrate solution only minute knobs were visible. Gradually a difference was also evident between the calcium nitrate and the calcium and strontium nitrate solutions, the root hairs in the former being long and numerous, while in the latter they were short and few. Moreover, when the strontium nitrate gradually attained an excess over the calcium salts stored up in the branches, the noxious effect became evident, they having attained a length after forty-two days of only 13 and 13.3 cm., with only two or three leaves on each branch, while those in the solution of calcium nitrate attained a length of 16, 17.2, and 18 cm., with six to seven leaves on each branch. The leaves of the former branches were partially dying, but those of the latter were still healthy. A control case with distilled water demonstrated beyond a doubt that in the case of the strontium nitrate solution the phenomena mentioned were not merely due to the absence of the lime, but to a direct noxious action of the strontium salts. The numerous root hairs which developed in the distilled water further justified the conclusion that lime salts were stored up in the stems. Indeed, the writer has demonstrated that besides sulphates, the nodes of the *Tradescantia* stems have stored up in them nitrates, potassium, and magnesium and calcium salts. An undeniable analogy appears to exist, therefore, between the noxious effect of the strontium salts and that of magnesium salts, both beginning to be noxious when the amount of lime falls below a certain limit.

A series of very instructive experiments were carried out by U. Suzuki[a] with five phanerogamous plants—*Hordeum*, *Fagopyrum esculentum*, *Phlox paniculata*, *Rubus idæus*, and *Coreopsis tinctoria*. Some of the plants were watered with a normal solution containing calcium in the form of calcium nitrate, and others with solutions in which the calcium nitrate was replaced by equivalent quantities of strontium nitrate and of barium nitrate. Only the plants in the normal solutions showed a strong and vigorous development, while those in the barium and strontium solutions exhibited gradually an injurious action.

[a] Bull. Coll. of Agr., Tokyo, 1900, Vol. IV, No. 1, "Can strontium and barium replace calcium in phanerogams?"

The action of the barium solution was more injurious than that of the strontium solution. Branches of the other three phanerogams mentioned were used; here those in the barium and strontium solution died after eight days, while those in the normal solution containing calcium nitrate remained healthy and developed new leaves. Control cases in distilled water showed also that the injury is due not merely to the absence of lime, but directly to a poisonous influence of the barium and strontium salts. Further tests showed that these poisonous actions are retarded by the addition of lime salts.

Now, if calcium salts perform and sustain processes of metabolism merely it might be inferred that such processes could be performed as well by strontium salts, the main properties of the salts of both elements being to a certain degree alike. Thus, strontium oxalate dissolves with difficulty in water (1:12,000), as does also the sulphate. The latter, however, being less soluble (1:6,895) than calcium sulphate (1:488), it might be supposed that the assimilation of sulphur is seriously lessened. However, considering the diluted state in which the phosphates enter and how well they are assimilated nevertheless, it is clear that the lesser degree of solubility of strontium sulphate would not be a serious obstacle to the assimilation of sulphur. It may, then, well be asked what kinds of processes of metabolism in plants have to be assumed for calcium salts which it would be impossible for strontium salts to perform.[a] Thus far the defenders of the metabolic theory have given no satisfactory explanation. The writer's previously mentioned theory on the function of lime salts, on the other hand, makes it perfectly clear why strontium salts in certain doses become hurtful and even poisonous for all organisms except the lowest forms of algæ and fungi.

POISONOUS ACTION OF MAGNESIUM SALTS.

If the writer's view that a calcium-protein compound participates in the organized parts of the nucleus and chlorophyll body is correct, it might be expected that magnesium salts of the stronger acids would exert a noxious action. The lime as the stronger base would in such a case combine with the acid of the magnesium salt, while magnesia would enter into the place which the lime had occupied in the organized structures, the capacity for imbibition would thereby be altered, and a disturbance of the structure would result which would prove

[a] Whether a gradual adaptation to strontium salts could ever take place, or, in other words, whether in the course of many generations strontium-protein compounds could gradually be utilized like the corresponding calcium compounds, is an entirely different question. However, in this connection only the simpler kinds of organisms might yield satisfactory results. It may be mentioned that 0.1 per cent strontium nitrate added to the culture water does not, even after months, injure diatoms, Flagellata, or Infusoria in presence of sufficient lime.

fatal. On the other hand, judging from the laws of the action of masses, it would naturally be inferred that an excess of lime salts would remedy the evil effects by making the reverse process possible. As a matter of fact, a detrimental action is observed when plants are treated with sulphate or nitrate of magnesium in the absence of calcium salts, an effect which is not observed when the same plants are exposed to the exclusive action of calcium, sodium, or potassium sulphate or nitrate. These phenomena were foreseen by the writer and may be readily explained by his theory, while the holders of other views have not come forward with an explanation.

The writer observed that *Spirogyra* died within four to five days in a 1 per mille solution of magnesium sulphate, but remained alive for a long time in corresponding solutions of sodium, potassium, or calcium. In a 1 per cent solution of magnesium nitrate smaller kinds of *Spirogyra* will die in from six to twelve hours, but will live a long time in corresponding solutions of sodium, potassium, and calcium nitrate. *Spirogyra* which had been kept for several weeks in a healthy condition in a solution of 0.1 per mille of monopotassium phosphate in absolutely pure distilled water died within three to four days when 2 per mille magnesium sulphate was added to this solution; but when dipotassium phosphate instead of the monophosphate was used, death set in much later; that is, after fifteen to eighteen days.

Some threads of *Spirogyra majuscula* placed in a solution (1 liter) containing 0.02 per mille each of magnesium nitrate and ammonium sulphate died in from ten to twelve days, while in the control solution, containing calcium nitrate in place of magnesium nitrate, they were still alive after six weeks, although cell division had stopped completely and the cells exhibited an emaciated appearance owing to the absence of other mineral nutrients. In still another case threads of the same alga were placed in a solution of 1 per mille of magnesium nitrate, while in the control case 3 per mille of calcium nitrate was added.[a] In the former case death resulted in five days,[b] while in the latter the cells were still alive after a number of weeks. Lime salts, therefore, are the antidote against the poisonous effects of magnesium salts.[c] Nothing can replace them successfully in this case, not even nourishment with organic matter.[d] Microscopical examinations of *Spirogyra* cells exposed to the exclusive action of magnesium salts show that the nucleus is attacked first and then the chlorophyll body is injured, the

[a] These observations the writer described in Flora, 1892, and also in Landw. Vers. Stat. of the same year.

[b] The time is probably prolonged when lime salts are stored up.

[c] An addition of strontium salts may delay death for a short period, but it can not prevent it, as do calcium salts.

[d] It may be mentioned that *Spirogyra* remains alive for from five to six weeks if kept in distilled water. Of course any further development is stopped, but assimilation and respiration soon reach a suitable equilibrium.

phenomena closely resembling those produced by potassium oxalate; but while in a 1 per cent solution of magnesium sulphate the nucleus will swell up after twelve hours, in a 0.5 per cent solution of potassium oxalate it will do so in a much shorter time.

The noxious action of magnesium salts also soon becomes evident in the roots of seedlings. Thus *Vicia* and *Pisum* do not start lateral roots when kept in a solution of 0.5 per cent magnesium sulphate or nitrate, and the root cap and epidermal cells die after a few days. In a solution of calcium nitrate of equal strength, however, development continues. Seedlings of *Phaseolus* placed in a solution of 0.1 per cent magnesium sulphate with 0.1 per cent monopotassium phosphate showed injury to the roots after five days, and the entire plant succumbed soon afterwards. Similar observations had been made by Wolff, by Raumer and Kellerman, and by others, but all failed to recognize the true cause and to ascertain that lime salts alone act as the specific remedy.

Raumer[a] observed that in *Phaseolus multiflorus* kept in various culture solutions there was a detrimental effect much sooner when lime alone was absent than when both lime and magnesia were absent. The difference was most striking in the main roots and also in the number and vigor of the lateral roots. Here, then, the noxious effect of magnesia in the absence of lime is again manifested.

The writer has made a special study of the development of roots in culture solutions free from lime and from magnesia, using branches of *Tradescantia* for this purpose. These have calcium as well as magnesium salts stored up in their nodes, and hence some development of roots is possible even in distilled water. Nevertheless, a most striking difference was noticed, the roots in the culture solutions containing lime, but not magnesia, producing a "dense forest" of root hairs that reached a length of one-fourth centimeter, while the roots in solutions containing magnesia but no lime, although larger than the others,[b] produced only a few short hairs. The lack of lime in these roots was felt especially in the epidermis, the interior parts being able to draw a sufficient amount of lime from the stem. Indeed, a microchemical test showed the presence of lime in the ash of these roots, gypsum needles forming when treated with a little sulphuric acid.

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[a] Landw. Vers. Stat., 1883, Vol. XXIX, pp. 254 and 268.

[b] These roots were 4.1 cm. long, while those in culture solutions without magnesia were only 3.2 cm. long. The composition of the complete culture solution in the above case was as follows:

	Per mille.
Monopotassium phosphate	0.1
Potassium nitrate	.5
Sodium sulphate	.2
Calcium nitrate	.5
Magnesium sulphate	.2
Ferrous sulphate	Trace.

The extraordinary effects of lime salts on the development of root hairs is of special interest, as it furnishes the key to the observation of Wolff that the potassium and ammonium salts of the soil are absorbed in increased quantities by plants after manuring with lime salts.

Magnesium salts do not, of course, rank with mercuric chlorid and other violent metallic poisons as to the degree of toxicity. Their injurious action, moreover, decreases in the same measure as the amount of calcium salts in the cells to be tested increases; it further depends upon the degree of protection of the nucleus against the entering salts, upon the thickness of cellular membranes, and, last but not least, upon the degree of acidity of the cell sap. Such differences will account for the observation of Kearney, that magnesium sulphate proves much more poisonous for seedlings of lupin and alfalfa than for those of maize, and for the recent observation of Duggar of the exceptionally low toxicity of magnesium salts for marine algæ. Wherever, further, the entering magnesium salt can be transformed in the cells into the secondary phosphate, there the toxic action becomes exceedingly weak, as the writer has himself proved (see above the experiment with *Spirogyra* made in presence of monopotassium and of dipotassium phosphate). The primary question is, Which magnesium salts react easily upon the calcium compounds of the nucleus?

LIFE WITHOUT LIME SALTS.

While lime salts are indispensable for animals, Phanerogams, and higher algæ, they are not so in the case of bacteria, fungi, and lower algæ. Thus far no investigations relating to the higher fungi have been made in this regard. The occurrence of lime in the ash of yeast and of tubercle bacilli[a] must be regarded as merely accidental. It was first observed by Adolph Mayer that for yeast magnesia is of greater importance than is lime. Later the writer proved that yeast and bacteria can do without lime entirely,[b] and Molisch has observed that this is also true of mold fungi.[c] It has been observed, on the other hand, that in certain cases the presence of lime promotes the action of fungi, but this is very probably due only to a secondary effect. Thus, the nitrification in soils is enhanced by calcium carbonate, and, according to Thaxter and Wheeler,[d] the scab of potatoes and of sugar beets is increased by liming the soil. Recently Laurent[e] reported that certain bacteria, *Bacillus coli communis* and *B. fluorescens putidus*, can attack potatoes

[a] According to de Schweinitz and Dorsett (Centralbl. f. Bakt., No. 23, 1898), the phosphates of sodium, calcium, and magnesium predominate in this ash over that of potassium, while the reverse is true in the ash of yeast.

[b] Flora, 1892, pp. 374 and 390.

[c] Ber. Wien. Akad., 1894, Vol. CIII.

[d] Storer, Relation of Agriculture, Vol. II, p. 546.

[e] Ann. de l'Institut Pasteur, 1899, Vol. XIII, p. 1.

in soils which have been strongly limed. He believes that by this means the power of resistance of these plants is diminished so much that the microbes named can commence their parasitic life, and he further asserts that only such plants can resist as have at the same time a great amount of potash and phosphoric acid.[a]

Both Molisch[b] and the writer[c] have observed that lime is not required by the lower forms of algæ. Molisch proved this in the case of *Ulothrix*, *Microthamnion*, *Stichococcus*, and *Protococcus*,[d] and the writer proved it in the case of a kind of *Palmella*.

Bipartition, zoospores, isogamy, and oogamy represent a scale of progress which probably requires an increasing differentiation of the nuclei. Isogamy in its simpler forms must be distinguished from its more perfected form, as it is found for instance in copulation of *Spirogyra*, where the uniting plasma bodies remain protected by the cellulose wall during the entire process. Some forms of the order *Protococcoideæ* multiply only by bipartition, others by swarm spores, certain forms by isogamy, but only two genera (*Volvox* and *Eudorina*[e]) by oogamy. In the order of the *Confervoideæ*, *Ulothrix* multiplies only by isogamy, while *Œdogonium* multiplies by oogamy also. In other groups a still higher potentialization of the nucleus has to be inferred, as in the *Characeæ* from the highly differentiated structure. Since neutral potassium oxalate has a poisonous effect upon *Diatoms*, *Œdogonium*, *Cladophora*, and apparently also on *Draparnaldia*, the presence of important lime compounds in these organisms may be inferred. All these organisms, however, are more differentiated than *Ulothrix*, which, according to Molisch, can grow in the absence of lime salts.

A careful study and comparison of the various chloroplasts of algæ might also show certain advantages in favor of those which require lime for their development. For instance, certain low genera, such as *Nostoc* and *Oscillaria*, form no starch, while others do. In such cases starch formation is to be regarded as a step forward, one that depends

[a] A satisfactory explanation of the decrease of power of resistance under the influence of such an important nutrient as lime would be very desirable. Perhaps the cells beneath the lenticels are thereby stimulated to growth and open a way for the parasites to enter.

[b] Sitzungsber. d. Wien. Akad. d. Wissenschaften, 1895, Vol. CIV. In this article Molisch has also proved that the algæ mentioned are incapable of assimilating free nitrogen. This confirms an earlier observation on *Nostoc* by the writer (Biol. Centralbl., Vol. X, p. 591) and a later observation by Kossowitsch.

[c] Botan. Centralbl., 1895, No. 52. Probably *Nostocaceæ* and *Oscillatoriaceæ* also do not require lime. The culture of *Oscillaria*, however, presents especial difficulties.

[d] It was not ascertained whether any other mode of multiplication than that by bipartition would be possible in the absence of lime in some of the forms mentioned. This question might also be raised in regard to fungi.

[e] It would be of special interest to ascertain whether, as seems probable, *Eudorina* and *Volvox* require lime salts.

upon a higher differentiation of the chloroplasts. The beautiful chloroplasts of *Spirogyra* show a high degree of differentiation, the pyrenoids in the chloroplasts being the manufacturers of the starch.

It is true Schmitz also observed well-defined chloroplasts multiplying by bipartition in such simple alga forms as *Protococcus*, *Stichococcus*, and *Palmella*, but these chloroplasts appear to be of a lower order than those of *Cladophora*, *Zygnema*, or *Spirogyra*.

The nutrition of the chloroplasts is in all probability cared for by the nucleus; hence it is reasonable to suppose that nuclei which prepare calcium-protein compounds for themselves furnish these same compounds to the chloroplasts also. This is probably the simplest explanation as to why chloroplasts become sensitive to even neutral oxalates in all plants the nuclei of which are killed by oxalates. Where the nuclei contain calcium-protein compounds the chloroplasts also contain them.

The writer has advanced the view that a higher development in form and function becomes possible only when the lower forms of life acquire the ability to assimilate lime and to utilize the resulting calcium-proteid compound for the construction of the nucleus. This seems to him the simplest explanation of the fact that lime salts are required by all plants except the very lowest forms. Agreeing especially well with this view is the further observation that neither neutral oxalates, nor magnesium, nor strontium salts are injurious to these lowest forms,[a] although noxious to all other plant life.

If lime were necessary only for certain processes of metabolism in plants, as some authors claim, it would not only follow that the higher forms of algæ have quite a different mode of metabolism from the lower ones, but it would also remain entirely incomprehensible why magnesium salts act so poisonously on the nucleus and why only calcium salts can prevent this deleterious effect. It would be very interesting to know the exact line of organisms below which calcium salts are not required and above which they are indispensable for plant life. A division of the algæ into two such groups would certainly prove instructive.

POSSIBLE RELATIONS BETWEEN LIME AND THE TRANSPORTATION OF STARCH.

One of the first disturbances to appear when there is a deficiency of lime is the cessation of starch transportation. Starch gradually accumulates in the lower parts of the stem, and even its transportation from the storage receptacles to the axial parts may gradually stop. It

[a] *Palmella* can develop quite well, even in 4 per cent solutions of neutral potassium oxalate or magnesium sulphate to which traces of ammonium sulphate and potassium phosphate had been added. Beer yeast may be kept for several hours at 30° C. in a 1 per cent solution of magnesium nitrate without serious injury.

has already been mentioned that a similar phenomenon was observed by Nobbe in plants showing a deficiency of chlorine compounds. Two causes, either separately or combined, may produce this phenomenon, and it follows, therefore, that the conditions bringing it on in different cases may not necessarily be wholly identical. One cause may be that cells fail to produce the diastase which is necessary for dissolving the starch, and another the impossibility of forming in the growing parts new plastids and chloroplasts, which produce starch from sugar.

The writer's view, according to which lime is required in the compounds which build up nuclei and chromatophores, explains not only the failure to increase these organoids, but also to produce diastase when lime is absent. Enzymes are secreted from the nuclei, as Hofer has shown with amœbæ, and therefore if the nuclei can not be normally formed for want of lime enzyme formation also may cease. However, this latter explanation does not seem to apply for the initial pathological stage, since Raumer and Kellerman observed that in *Phaseolus multiflorus* sugar also was formed from starch for a certain period when lime was deficient; hence diastase was probably present.

In this case the upper part of the stem was devoid of starch and seemed to be incapable of forming starch from the sugar present. This accumulation of sugar prevented any further solution of starch in the lower parts.

The intensity of starch transportation depends essentially on two factors, (1) the saccharifying activity and (2) the starch-forming activity of the leucoplasts in other parts of the plants.

Further investigations in this direction would be very desirable. They would perhaps also show differences between the action of chlorids and that of lime in regard to the transportation of starch. Finally, since a deficiency of lime, like the absence of phosphoric acid, potassa, or magnesia, stops the formation of new cells, an accumulation of proteins may result, and indeed such a case was observed by Stock, the crystalloids increasing in number when lime was deficient.[a]

THE PHYSIOLOGICAL RÔLE OF MAGNESIUM SALTS.

It has already been pointed out that magnesium salts are especially important in the formation of seeds, but they are also required by all other parts of plants, and especially in the process of development. The amount of magnesia taken up by crops varies considerably. For example, an average crop of wheat will take up 8 kilos per hectare, a crop of leguminous plants 12 kilos, and a crop of tobacco as much as 43 kilos. It has also been pointed out that magnesium salts can fulfill their nourishing functions only in the presence of calcium salts, while in the absence of calcium salts they even exert an injurious action.[b]

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[a] Bot. Centralbl., Vol. LIII, p. 83.

[b] Only the lowest algæ and fungi are exceptions

In studying the questions as to what the nourishing function of magnesium salts is and why they can not be replaced physiologically by calcium salts, the probable answer is found in the well-known property of the magnesium salts to undergo dissociation easily, as the writer pointed out some years ago.[a] Magnesium salts are easily hydrolyzed, as is shown in the preparation of chlorid or carbonate of magnesium by the ordinary method, whereby a part of the acid is easily liberated. Moreover, in boiling with water the secondary magnesium phosphate is decomposed into tertiary phosphate and free phosphoric acid. The inference suggests itself that this easy dissociation is of great value to the cells, since in the assimilation of nitrogen from nitrates, sulphur from sulphates, and phosphoric acid from phosphates the dissociation of these salts would immediately precede assimilation; hence the easier these acids are separated from the base the easier their assimilation will be accomplished. However, this deduction relates more to the assimilation of phosphoric acid than to that of sulphur and nitrogen. This latter assimilation must be possible also, to a certain degree, from other sulphates and nitrates besides those of magnesia.[b] According to this view the formation of nucleoproteids depends upon the presence of magnesium salts. As a matter of fact, it is found that magnesia always increases where rapid development is taking place. In accordance with this view also, small quantities of magnesium salts can be used for a great deal of work, since the same amount of base can serve over and over again as the vehicle for assimilation of phosphoric acid. This may also explain the fact, pointed out long ago by Adolph Mayer, that "magnesia is more movable in the plant than lime is," and that "magnesia, like the phosphates, follows the proteids."

The fact that comparatively little magnesia can serve for extended physiological operations may be noticed in fungi in culture solutions devoid of lime, and also when seeds are left to develop in culture solutions free from magnesia and with only a moderate amount of lime in proportion to phosphoric acid. For example, beans may reach even 1 meter in height in such solutions, the reserve magnesia sufficing for this result.

Besides the easy dissociation the solubility of the secondary magnesium phosphate in water is also of value. This solubility is much greater than that of the secondary calcium phosphate. When 100 cc. of a 0.2 per cent solution of disodium phosphate are mixed with 2 to 3 cc. of a 10 per cent solution of magnesium nitrate at the ordinary temperature no precipitate is formed, while with an equivalent amount of calcium nitrate there will be a considerable precipitate. It may be inferred, therefore, that the secondary magnesium phosphate is more

[a] Flora, 1892, p. 286.

[b] It is important to remember that nitrates and sulphates are reduced in their assimilation while phosphates are not.

capable of migrating in plants than is the calcium phosphate, at least in neutral media and in the cytoplasm and its intercellular connections.

The alga *Spirogyra* is especially well adapted to show the influence of magnesium salts upon the production of portein matter. This influence may be twofold, (1) in facilitating the assimilation of sulphur and nitrogen from sulphates and nitrates the albumin formation as such is increased, and (2) in making the assimilation of phosphoric acid possible, nucleoproteids may be formed, so that division of the nucleus and growth can proceed. If growth is as energetic as the formation of protein no accumulation of protein will take place, all being organized for the wants of the multiplying cells. However, by reducing the amount of phosphate to a trace multiplication can be very much retarded or stopped altogether, while albumin formation may go on; hence in this case an accumulation of albumin takes place either in the cell sap or in the cytoplasm or in both.

These conclusions can be very easily verified by studies with *Spirogyra*, for which the bicarbonate, obtained by dissolving magnesium carbonate in water charged with carbonic acid, is a very favorable form of magnesium. Thus a most energetic growth was observed with the following composition:

	Per mille.
Magnesium bicarbonate	0.5
Magnesium sulphate	.1
Calcium nitrate	.5
Monopotassium phosphate	.05
Potassium nitrate	.2
Ferrous sulphate	Trace.

The supposition that the favorable action of the magnesium bicarbonate consists simply in a "neutralization of acids" formed in the process of metabolism, can not be correct, since calcium bicarbonate by no means shows the same beneficial influence, and besides in the latter case the above culture solution would contain such an excess of lime over magnesia that the assimilation of phosphoric acid might be retarded, involving a slower development.

The foregoing makes it intelligible why in the absence of magnesium salts the multiplication of cells is stopped, the nucleus not being able to increase to the point where division sets in. In the mixture of different salts occurring in plants there is sufficient opportunity for magnesia to combine with phosphoric acid, and the secondary magnesium phosphate thus formed can, in passing into the tertiary salt, yield some free phosphoric acid. The tertiary salt remaining can easily be redissolved by weak organic acids, and thus yield again the secondary phosphate, which may in turn be utilized for the assimilation of phosphoric acid. Rapidly growing parts generally develop an acid reaction in the cell sap, which is of advantage.

The rapidly proceeding cell division requires the most favorable conditions for the assimilation of phosphoric acid.

Thus far few authors have expressed any view as to the primary functions of magnesia. Raumer observed that *Phaseolus multiflorus*, grown in culture solutions without magnesia, reached 1 meter in height, after which the internodes no longer lengthened, but thickened abnormally. The new leaves also remained small and ceased to produce chlorophyll—an interesting case of chlorosis, which disease may be produced by other causes than by the absence of iron, as has been already pointed out. Raumer ascribed to magnesia and not to lime, as Boehm has done, the transportation of starch, basing his claim on the ground that in the beginning the leaves contain not only considerable starch, but also a relatively large proportion of magnesia, a condition found later also in the stems. Finally, magnesia is found to be increased in the seeds, in which starch also is generally deposited. This hypothesis does not, however, seem to be well founded, since the relations indicated are not direct ones. Many other facts make it much more probable that it is the proteids and not the starch that have a close relation to magnesia. Where development is going on, starch is required for furnishing the necessary carbon and hydrogen in the production of proteids. Here magnesia is connected with the protein production and not with the migration of starch. Furthermore, the organoids of starch formation, the plastids, also require magnesium salts for their growth and multiplication, since they contain phosphoric acid in their nucleo-proteids; hence there also exist some reasons for the belief in the remote connections between the starch content of an organ and the amount of magnesia present.

INCREASE OF MAGNESIA IN OILY SEEDS.

If the writer's theory as regards the relation of magnesia to phosphoric acid is correct, more magnesia ought to be found where both compounds, nucleoproteids as well as lecithin, are formed than where nucleoproteids alone exist, since the assimilation of phosphoric acid is required not only for the formation of nucleoproteids, such as chromatin and plastin, but also for that of lecithin. Lecithin is a constant concomitant of fat, and therefore seeds rich in fat ought to contain, cet. par., more magnesia than such as are rich in starch. A review of Wolff's ash tables confirms this deduction. For 1,000 parts of organized substance there are of magnesia in—

Starchy seeds.		Oily seeds.	
	Parts.		*Parts.*
Oats	1.9	Cotton	5.6
Barley	2.0	Flax	4.7
Rye	2.0	Poppy	4.9
Maize	1.9	Pape	4.6

The average proportion of magnesia in starchy seeds to that in oily seeds, therefore, is as 2 to 5.

It may furthermore be pointed out that fungi grown in culture solutions containing only traces of magnesia form no spores. Spores, however, contain lecithin, and in all probability relatively large amounts of nucleoprotein. Here the importance of magnesia can be readily demonstrated by increasing its amount in the culture solution, after which spores are soon formed. A similar effect on oats was observed by Schneidewind.[a] Of all nitrates tested, magnesium nitrate yielded the largest grain production.

NECESSITY OF MAGNESIUM SALTS FOR FUNGI.

Magnesium salts are also indispensable for fungi, but an exceedingly small amount will suffice when the nourishing solution has an acid reaction. In fact, even traces of magnesia taken up from glass vessels, if the latter are not made of the most resistant material, will suffice for growth. Fränkel denies the necessity of magnesia for certain kinds of bacteria[b]—*Bacterium coli*, *B. pyocyaneus* Friedl., and other bacteria having been cultivated by him in solutions of aspartate or lactate of ammonia in absence of magnesium salts. However, a suspicion as to the absolute purity of his materials may be justly entertained.

How small a quantity of magnesium salts may suffice for mold fungi is shown by the following observation: The writer prepared a nourishing solution containing 2 per cent of ammonium acetate, 0.04 per cent monopotassium phosphate, and 0.02 per cent potassium sulphate and infected the solution, which was made with absolutely pure materials, with a few spores of *Penicillium*, but obtained no growth, owing to the absence of magnesia. He then added 0.0003 per cent of magnesium sulphate, and soon a considerable development of mycelium took place, its weight finally becoming very nearly the same as that in the control flask containing 0.1 per cent of magnesium sulphate.[c] The only difference observed between the two cases was that in the former flask spores were entirely absent, while in the latter they were abundantly formed.

Günther[d] inferred from his experiments that the limit of sensibility of the fungus *Rhizopus* to magnesium sulphate is 0.005 milligram. From such experiments it seems very probable that in those made by Fränkel with bacteria traces of magnesia were present as impurities in some of the compounds used.[e]

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[a] Journ. f. Landw., 1898, Vol. XLVI, p. 1.

[b] Centralbl. f. Bakt., Vol. XVII, p. 32.

[c] Experiments with *Penicillium* succeed best in moderately acid solutions.

[d] See p. 33.

[e] This applies also to the belief of Thumm that magnesium can be replaced by calcium in the culture of certain bacteria, as *B. pyocyaneus*.

Molisch has observed, and his observations have been confirmed by the writer, that spores of *Penicillium* do not even germinate in culture solutions entirely free from magnesia and containing ammonium acetate as the only organic nutrient—a fact which appears very strange, as there is certainly stored up in the spores a sufficient amount of magnesium phosphate to make germination and even some further development possible, and indeed magnesia has been found repeatedly in the ash of fungi spores. The writer has cultivated *Penicillium* in a solution containing peptone, tartaric acid, monopotassium phosphate, and 0.1 per cent magnesium sulphate, and has convinced himself of the presence of magnesia in the spores.[a] However, these same spores did not germinate in the solution of ammonium acetate used by Molisch and by the writer, but they germinated in various other solutions, as, for instance, in a 0.5 per cent solution of sodium acetate or of cane sugar containing a small amount of ammonium sulphate. It appears probable, therefore, that a solution containing ammonium acetate as sole organic nutrient is unfavorable for starting in the spores certain processes which render the stored-up magnesium phosphate available for the beginning of germination. Perhaps there is formed in the spores magnesium ammonium phosphate which is but little soluble when too much ammonia is present in the culture solution. In suitable culture solutions, free of magnesia, the magnesium phosphate stored up in the spores may be economically utilized, and even a considerable mass of mycelium may be produced, provided an abundant sowing of spores had taken place. This explains the contradictory results obtained by some authors.

CAN MAGNESIUM SALTS BE REPLACED BY BERYLLIUM SALTS?

Former attempts to clear up the physiological functions of magnesium naturally have raised the question whether beryllium can perform the functions of magnesium in living cells, since the general behavior of the compounds of both elements bears a strong chemical resemblance.

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[a] It has been shown by Aso that the spores of *Aspergillus oryzæ* contain a moderate amount of magnesia. The ash of these spores had the following composition:

	Per cent.
Potash	45.96
Soda	4.13
Lime	1.03
Magnesia	4.36
Ferric oxid	4.91
Phosphoric acid	39.64
Sulphuric acid	2.00
Silica	.40

The percentage of ash in the dry matter was 5.15. The fungus had been grown on boiled rice.

In 1890 Sestini[a] undertook to determine whether wheat could be raised in culture solutions in which magnesium sulphate was replaced by beryllium sulphate. He sowed the grains in quartz sand which had been treated with hydrochloric acid to remove all mineral impurities, and watered the plants with a culture solution containing beryllium sulphate in place of magnesium sulphate. The plants reached a height of 90 to 95 cm., but the control experiment showed the superiority of magnesium over beryllium, as will be seen by the following comparison:

Wheat grown—	Number of seeds.	Weight of seeds.	Weight of single seed.
		Grams.	*Grams.*
In the beryllium solution	283	12.31	0.435
In the magnesium solution	322	15.20	.472

The harvested seeds were grown again in the same way.[b] Of twenty seeds of the plants grown in beryllium solution, however, only seven germinated, and only three of the plants produced seeds, the resulting crop of fourteen seeds weighing only 0.37 gram and averaging only 0.026 gram. This clearly shows that beryllium can not replace magnesium in wheat, and very probably also not in any other of the phanerogams. The fact that the first generation yielded a much better result than the second must be ascribed to the presence of a relatively large amount of magnesium phosphate in the seeds used.

In an experiment made by the writer with shoots of *Tradescantia* placed in culture solutions containing 0.1 per cent beryllium sulphate in one case and 0.1 per cent magnesium sulphate in the other, the lower leaves of the beryllium plant commenced to die after several weeks, and the newly developed upper leaves scarcely reached one-third the normal size, these shoots dying off after eight weeks, while in the control case they were still in a healthy condition.[c]

In regard to algæ, the writer has observed that a solution of beryllium sulphate in which the other mineral nutrients are wanting exercises an injurious influence sooner than does the magnesium sulphate. Some threads of *Spirogyra communis* were placed in 0.2 per cent of these salts dissolved in purest distilled water, and it was found after two days that the number of dead and injured cells was much larger in the former case than in the latter.[d]

In a subsequent experiment the amount of both these sulphates was

[a] Le Staz. Agr. Ital., Vol. XX; Centralbl. f. Agr. Chem., 1890, p. 464, and 1891, p. 558.
[b] The ash of the beryllium plants contained 2 per cent of BeO.
[c] Mineral nutrients are stored up in the nodes, as already mentioned.
[d] For further information relative to the noxious effect of magnesium salts in absence of calcium see pp. 49–51.

diminished and mineral nutrients added, the composition of the main solution being—

	Per mille.
Calcium nitrate	0.10
Calcium sulphate	.01
Monopotassium phosphate	.01
Dipotassium phosphate	.01
Beryllium sulphate	.10

In this solution *Spirogyra* threads were still normal and healthy after three weeks, but had not grown to any noticeable extent.

In another experiment the following solution was prepared:

	Per mille.
Calcium nitrate	0.25
Calcium sulphate	.10
Monopotassium carbonate	1.00
Monopotassium phosphate	.05
Ferrous sulphate	Trace.

One-half of this solution received 0.2 gram magnesium sulphate and the other half 0.2 gram beryllium sulphate. Very soon a slight turbidity, followed later by a flocculent precipitate, was noticed in the beryllium solution, while the control solution remained absolutely clear. Into both flasks a trace of a *Palmella* culture, with some Diatoms, was now introduced. After four weeks it was found that the Diatoms had multiplied to a great extent in the control solution, but not one could be observed after repeated microscopical examinations in the beryllium solution. The *Palmella*, however, was well developed in both flasks. This might seem to indicate that such a simple alga form as *Palmella* could utilize beryllium salts in place of magnesium salts, at least when offered in a favorable culture solution; but slight traces of magnesia might have been furnished by the glass vessel.

To determine the effects of beryllium on fungi an experiment was made by Molisch, the culture solution used containing—

	Per mille.
Ammonium acetate	20.00
Beryllium sulphate	.40
Monopotassium phosphate	.04
Ferrous sulphate	.01

There was no development whatever in this solution when spores of *Penicillium* were inoculated, but upon the addition of 0.02 per cent magnesium sulphate 78 milligrams of fungous mass was produced after nineteen days.

Notwithstanding the close chemical relations between beryllium and magnesium there must exist such chemical differences that the inability of beryllium to physiologically replace magnesium can be easily explained. As the text-books on chemistry fail to give minute comparisons of the chemical behavior of soluble beryllium and magnesium salts toward phosphates, the writer has made a few tests in this regard. When 1 per mille solutions of beryllium sulphate and dipotassium phosphate are mixed the liquid is at first clear at the ordinary temperature, but gradually becomes opalescent, and after one day the beryllium is precipitated as a flocculent phosphate, but if the mixture is heated or if some sodium acetate is added a flocculent precipitate is produced at once. Magnesium sulphate behaves very differently, giving no precipitate whatever under the same conditions.

If a 10 per cent solution of monopotassium phosphate is mixed with a 10 per cent solution of magnesium sulphate no precipitate is formed at the ordinary temperature, and the liquid remains clear even on boiling. This, however, is not the case with beryllium sulphate, which produces a copious flocculent precipitate in a few minutes, and even if more dilute solutions, as, for example, a 1 per cent solution of monopotassium phosphate and beryllium sulphate, are mixed, the mixture becomes turbid on boiling.

Although a higher diluted solution of beryllium sulphate gives no precipitate with monopotassium phosphate, the addition of sodium acetate, even at the ordinary temperature, will cause a precipitate of beryllium phosphate. Thus even in a dilution of 0.001 per cent beryllium sulphate turbidity will be produced, and finally some flocculi will be deposited. Under the same condition solutions of magnesium sulphate, whether highly or moderately diluted, will remain perfectly clear.

It is seen, therefore, that there is a fundamental difference between beryllium and magnesium salts in their behavior to phosphoric acid—a difference which amply accounts for the fact that beryllium salts can not replace magnesium salts as far as the process of the assimilation of phosphoric acid is concerned. In this respect magnesium is unrivaled even by the most closely related elements. With the properties of easy dissociation of the salts and its character as only a weak base, magnesia unites a moderate solubility of the secondary phosphate not found with any other related base. Although beryllium oxid is also a weak base, the fact that it is much more inclined than magnesia to yield an insoluble phosphate renders it unsuitable for the function mentioned.

As to the rarer elements it may still be questioned whether there may not exist among them some that could physiologically replace magnesium or calcium. The experiments with cerium and lanthanum showed no evidence in favor of that view, these salts killing algæ in a solution of 0.1 per cent. Thorium sulphate is not so injurious, but no further studies as to whether it can be utilized for any physiological function have been made, nor have any experiments been made with yttrium, niobium, or some other rare elements.

IMPORTANCE OF LIME SALTS FOR ANIMALS.

In animals lime salts are necessary, not simply for the formation of the bones but also for every part of the body, and they are required for the lowest forms as well as for the higher animals.

The action of the heart is above all most intimately connected with the presence of lime salts. Thus a frog's heart will soon stop even in a physiologic salt solution (0.6 per cent sodium chlorid), but will continue to beat when some ash of blood is dissolved in the same solution. Ringer has shown that a good circulating fluid for the heart may be compounded by preparing a mixture of such salts as normally occur in the blood. In such a solution the isolated frog's heart will beat almost as long as it would in defibrinated blood. Halliburton[a] says: "The necessity for lime salts is especially great. In fact, the close adhesion of proteids generally with small quantities of mineral matter is rather suggestive of combination than mere mixture. Lime salts adhere especially closely and in fact seem indispensable for many of the functions of the body, of which the beating of the heart and the contraction of skeletal muscle are good examples. Blood from which the salts have been removed keeps the heart going, but the tracing is abnormal, resembling that produced by a weak solution of a lime salt. It is in fact found that dialysis will not remove the lime from serum albumin, though it removes the greater part of the sodium and potassium salts."

The great importance of calcium salts for the various organs of animals is also illustrated by the empirical knowledge gained by physicians. Thus a prominent medical work[b] states: "Calcium chlorid is used with benefit as an internal remedy in the various manifestations of the strumous diathesis. It often causes the resolution of glandular enlargements and the calcification of tubercular deposits, aids the cicatrization of ulcerating cavities, and has proved curative in eczema and lupus. It is highly praised in phthisis, also in chorea, and for the colliquative diarrhea of strumous children. In solution used externally as a fomentation it is said to hasten the maturation of boils." In direct contact with the heart, however, this salt is not harmless, as shown by the experiments with a frog's heart. Probably a hydrolytic dissociation, with liberation of hydrochloric acid, however slight it might be, brings on the injurious effect.

Munk[c] observed during the inanition of men and dogs a gradual increase of the lime secreted in the urine. Katsuyama[d] noticed in observations on starving rabbits in the first four days a gradual decrease and afterwards a slow increase of lime in the urine, while there was a

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[a] Chem. Physiol., London, 1891, p. 256.

[b] O. L. Potter, Handbook of Materia Medica, Pharmacy, and Therapeutics, Philadelphia

[c] Suppl. zu Virchow's Arch., Vol. CLI.

[d] Zeitschr. f. Phys. Chem., 1899, Vol. XXVI.

gradual and steady decrease of magnesia. This decrease of magnesia, compared with the increase of lime, is very significant and instructive.[a]

PROPORTIONS OF LIME AND MAGNESIA IN ANIMAL ORGANISMS.

The muscle fibrillæ of the mammalia are made up principally of the contractile substance, or, as Kupffer has called it, the dynamoplast. The energide (the nucleus with its connected cytoplasm), which manufactures the fibrillæ, occupies but a small volume within the dynamoplast, hence the writer's hypothesis would suggest the inference that the lime content of muscular masses should be less than that of glandular masses, since the relative mass of the nucleus in muscles is much smaller than in glands. From Katz's analyses the following data will show how far this view is confirmed.[b]

There were found in 1,000 parts of fresh muscle of a—

	Part calcium.
Dog	0.0685
Hog	.0806
Deer	.0959
Cat	.0846
Man	.0748

or an average of 0.0809 part calcium. On the other hand, Oidtman[c] found in the liver, the largest gland in mammalia, 0.284 part of calcium for 1,000 parts, or nearly three and a half times as much as the average in the muscle.

Embryos and young animals show a higher percentage of nuclear mass in the muscles than do full-grown animals, hence the fact that the muscles of the calf contain more lime than those of the cow[d] is in full accord with the writer's inference. Zoologists have further observed that the muscles of fishes and batrachia are relatively richer in nuclear mass than are those of mammalia. The fact that Katz[e] has found two to three times as much lime in the muscles of such animals as in those of

[a] It may be pointed out here that lime compounds also play an important rôle in the coagulation of the blood, as this can be prevented by the addition of some soluble oxalate. Myosin, which possibly plays a part in the coagulation of the muscular plasm, also contains lime. Moreover, the actions of rennet and of pectase are connected with the presence of lime. In the absence of lime no precipitates are formed, although the chemical changes by those enzymes are not prevented.

[b] Pflüger's Arch., Vol. LXIII, p. 1.

[c] Prize Treatise, Würzburg, 1858. This author found 1.1 per cent inorganic substance in the liver, and in 100 parts of this ash 3.62 per cent of lime and 0.19 per cent of magnesia. Calculating from these data, there are contained 0.2842 part of calcium and 0.0125 part of magnesium in 1,000 parts of fresh liver. The amount of magnesium is probably somewhat too low.

[d] The lime content of the liver cells is also larger, according to Krüger (1895), in the calf than in the cow, which suggests the necessity of further microscopic comparison as to the relative size of the nuclei.

[e] Pflüger's Arch., Vol. LXIII, p. 1.

mammalia is therefore strictly in accord with the writer's view. There is in 1,000 parts of fresh muscle of the—

	Part calcium.
Frog	0.1566
Shad	.2206
Eel	.3913

or an average of 0.2562 part calcium.

The importance of lime for the division of cells even in the lower animal organisms is shown by Herbst's statement[a] that the most important salt for the development of the sea urchin's eggs is calcium phosphate, in the absence of which not even the completion of segmentation is possible. The calcium of this salt is just as important as the phosphoric acid.

A relative increase of magnesia can be observed in organs in which the nuclear mass is small. Thus the human brain contains more magnesium than calcium,[b] and the muscles of mammalia contain in most cases more magnesia than those of batrachia and fishes, as shown by Katz's results.

There is in 1,000 parts of fresh muscle of the—

	Part magnesium.
Dog	0.2370
Hog	.2823
Deer	.2906
Cat	.2863
Man	.2116
Average	.2611

while there is in 1,000 parts of fresh muscle of the—

	Part magnesium.
Frog	0.2353
Shad[c]	.1670
Eel	.1782
Average	.1935

A comparison of the averages shows for the—

	Calcium.		Magnesium.		Calcium.		Magnesium.
Muscles of mammalia	1	:	3.23	or	0.31	:	1
Muscles of frogs and fish	1	:	.75	or	1.33	:	1

Since it is seen that glands contain more calcium than muscles, and that the muscles of lower animals contain more calcium than those of

[a] Arch. f. Entwicklungsmechanik, Vol. V, p. 667.

[b] If the gray and white matter of the brain are separately analyzed, however, it is found that the gray matter is richer in calcium than the white, as Toyonaga has shown. This is again in accordance with the increase of nuclear mass in the former. It holds good also after the fatty matter is eliminated in both cases. In 1,000 parts of the gray matter of calf's brain was found 0.367 part of lime, while in the white matter but 0.057 part.

[c] The unusually large proportion, 0.3102 part, found by Katz in the pike, may possibly be due to an error.

the higher animals, one can not help seeking for a law underlying these facts, which are in full accord with the writer's inference *that the amount of lime must increase with that of the nuclear mass.*

In this connection it is of some interest to compare the decrease of magnesium with the increase of calcium observed in the glands, as shown in the following statement:

Ratio of calcium to magnesium in certain tissues of animals.

For the muscles of mammalia	0.31	(Katz).
For the white matter of brain (calf)	1.14	(Toyonaga).
For the white matter of brain (horse)	0.30	(Toyonaga).
For the gray matter of brain (calf)	1.72	
For the gray matter of brain (horse)	2.80	
For the glands:		
Pancreas (cattle)	6.13	(Gossmann, 1899).
Pancreas (man)	4.75	(Gossmann, 1899).
Pancreas (man)	1.73	(Lüning, 1900).
Pancreas (?)	4.05	(Alog, 1900).
Spleen (cattle)	2.52	(Ribaut, 1900, average of 3 determinations).
Spleen (?)	6.79	(Alog).
Pulp of spleen (cattle)	3.45	(Ribaut, Jahresbericht für Thierchemich., vol. 30, p. 492).
Connective tissue of spleen (cattle)	2.70	(Ribaut, Jahresbericht für Thierchemich., vol. 30, p. 492).
Kidney (?)	1.84	(Alog).
Kidney (cattle)	2.90	(Gossmann).
Kidney (man)	4.25	(Gossmann).
Lactiferous gland (cow)	4.69	(Toyonaga).

No clear observer will deny that there must be a reason for this different ratio in all organs rich in nuclear mass compared with the ratio found in muscles and the white matter of the brain.

Some data regarding the absolute amounts of calcium and magnesium in the dry matter may be added. In 100 parts of dry matter of the organs there is—

Elements.	Muscles of mammalia.	Spleen (Ribaut, average).	Lactiferous gland (Toyonaga).
	Per cent.	*Per cent.*	*Per cent.*
Calcium	0.0337	0.141	0.173
Magnesium	.1090	.056	.038

BEHAVIOR OF ANIMALS TO STRONTIUM SALTS AND OXALATES.

The replacement of calcium salts by strontium salts is just as impossible in animals as in plants. Not even in the formation of the bones can strontium phosphate take the place of calcium phosphate. Craemer fed a rapidly growing young dog for several months with food poor in lime, and to which an addition of strontium phosphate was made, and as a result great softness of the bones and rachitic alterations were soon obvious. Weiske arrived at the same conclusions and refuted the contrary opinions of Papillion and König. In the presence of sufficient lime the poisonous action of strontium salts upon animals is weak.

The writer's hypothesis as to the functions of lime salts makes the poisonous action of soluble oxalates upon animals also more intelligible than it has been heretofore. The chief property of oxalates is to transform the calcium of calcium compounds into calcium oxalate. If, therefore, the nuclei of the cells contain calcium protein compounds in their organized structure, the removal of this calcium and its replacement by the sodium or potassium of the oxalate applied must alter the capacity of imbibition, and thus cause fatal disturbances of the organized structure. Indeed, oxalates constitute a general poison for all kinds of animals.[a] The writer has demonstrated that in a 0.5 per cent solution of neutral potassium or sodium oxalate *Rotatoria*, *Copepoda*, and acquatic *Asellids* die in thirty to fifty minutes, leeches and *Planaria* succumb a little later, and finally *Ostracodes* and larvæ of insects are killed. *Infusoria*, *Flagellata*, and *Amoebæ* were found to be dead in this solution after fifteen hours. Even a 0.1 per cent solution of sodium oxalate will kill some of the organisms named, such as *Copepoda* and *Rotatoria*. The poisonous action for vertebrates was known long ago, but the explanations were not entirely satisfactory. Some authors sought the cause in the obstruction of the vessels of the kidneys with calcium oxalate and in inflammation of the kidneys, and others believed in a decomposition of the oxalic acid with the production of the poisonous carbonic oxid, but the irritation and the final paralysis of the vasomotoric center pointed plainly to another cause.[b]

FINAL REMARKS.

The writer's deliberations have led him to conceive the probable rôle of calcium and magnesium salts in the living cells. This view is in full accord with various facts for which in former times no satisfactory explanation was reached.

It is now clear why magnesium is more movable in plants than calcium, and, further, why the calcium content increases with the mass of nuclear substance and of chlorophyll bodies, and why magnesium salts increase wherever phosphoric acid is in increased demand for the production of lecithin and nuclein. It also makes it perfectly clear why,

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[a] Noxious effects on the bones and kidneys and sometimes on the activity of the heart have been noticed after feeding cattle with vegetables containing soluble oxalates, such as leaves of the sugar beet.

[b] The fact long known to photographers, that badly healing sores are produced when open wounds come in contact with oxalate solutions, deserves particular mention.

on the one hand, magnesium salts become poisonous in the absence of calcium salts, and why, on the other hand, the absence of magnesium salts in an otherwise complete culture solution leads to a gradual stoppage of all further development and to final inanition. The formation of the nuclei and plastids requires calcium as well as magnesium salts, the former for the production of calcium nucleo-proteids and the latter for making possible the assimilation of phosphoric acid. If lime salts are in great excess in a neutral medium, the formation of magnesium phosphate, and consequently the assimilation of phosphoric acid, will be retarded, since the lime as the stronger base will withhold phosphoric acid when soluble phosphates come in contact with lime salts. Many plants, therefore, which have absorbed too much lime and relatively too little magnesia from the soil precipitate a part of the lime in the form of oxalate. Indeed, Monteverde[a] observed that the amount of oxalic acid increases with the amount of lime absorbed.

The excess of lime is in reality the cause of an increased production of oxalic acid—a fact best explained by the assumption that before carbonic acid is finally produced by the combustion of carbohydrates a series of organic acids, of which oxalic acid is one stage, is rapidly passed, this stage being fixed by the presence of lime. Similar observations were also made by Wehmer with fungi in culture solutions to which lime salts were added. In the presence of lime salts there was more oxalic acid formed than in its absence, or, more correctly expressed, more was preserved from being again destroyed by further oxidation.

The fact that seeds generally contain much more magnesia than lime may be considered an interesting case of adaptation. A rapid development by an easy assimilation of the reserve phosphoric acid is thus assured—a favorable circumstance, as it lessens the danger of the molding and putrefying of the seeds sown in moist ground. The same plant, when it develops chlorophyll, however, requires more lime in proportion to magnesia than does the seedling in its early stages.

According to Wolff's calculations of the minima of lime and magnesia for oats there is required 0.20 per cent of MgO and 0.25 per cent of CaO for the dry matter, but for plants with more abundant foliage the minimum of lime would be larger. The proportion of these two constituents in the soils is a more potent factor in the resulting crop than is generally supposed. The many contradictory statements in regard to the influence of magnesia in the soils are easily explained by the aid of the above theory. A soil rich in magnesia will be damaged by liming with magnesian limestone, since this would increase still more the already large amount of magnesia, while a soil very poor in magnesia may be benefited by it. In the application of kainit and carnallit not only the chlorids but also the magnesia content

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[a] Bot. Jahresber. f. 1890, p. 75.

of these potash fertilizers has to be considered, and eventually liming has to be carried on in conjunction with it.

A question, then, of considerable importance for agriculture is the judicial regulation of the lime and magnesia content of the soil, especially when mineral fertilizers are employed. This regulation must be based on the knowledge of the readily assimilated amounts of these bases. Hence only the finer soil particles should serve for analysis. When a soil is much richer in magnesia than in lime extensive liming is necessary. The liming should be done chiefly with the carbonate and only in part with slaked lime and the sulphate. On the other hand, when the magnesia content is much less than that of lime the addition of a powdered magnesian limestone or magnesite is necessary. Burned magnesite and artificially precipitated magnesium carbonate must be avoided under all circumstances, since they are too finely divided and too easily absorbed.

Experiments to determine the most favorable ratio of lime to magnesia have recently been made by D. W. May (1900), in Washington,[a] and by K. Aso and F. Furuta (1901), in Tokyo.[b] The results of these experiments show that cereals thrive best when the lime content of the soil only slightly exceeds that of magnesia. Crops having more abundant foliage, however, require considerably more lime. For the most luxuriant development cabbage needs twice as much lime as magnesia, while buckwheat requires three times as much lime as magnesia.

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[a] Bull. 1, Bureau of Plant Industry, U. S. Dept. of Agriculture, The Relation of Lime and Magnesia to Plant Growth, Washington, 1901. [On page 34 read 0.05 cm. and 0.02 cm. instead of 0.5 cm. and 0.2 cm.]

[b] Bull. College of Agriculture, Tokyo, 1901, Vol. IV, No. 5.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 46.

B. T. GALLOWAY, *Chief of Bureau.*

THE PROPAGATION OF TROPICAL FRUIT TREES AND OTHER PLANTS.

BY

GEORGE W. OLIVER, EXPERT.

SEED AND PLANT INTRODUCTION AND DISTRIBUTION.

ISSUED AUGUST 8, 1903.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1903.

BULLETINS OF THE BUREAU OF PLANT INDUSTRY.

The Bureau of Plant Industry, which was organized July 1, 1901, includes Vegetable Pathological and Physiological Investigations, Botanical Investigations and Experiments, Grass and Forage Plant Investigations, Pomological Investigations, and Experimental Gardens and Grounds, all of which were formerly separate Divisions, and also Seed and Plant Introduction and Distribution, the Arlington Experimental Farm, Tea Culture Investigations, and Domestic Sugar Investigations.

Beginning with the date of organization of the Bureau, the several series of Bulletins of the various Divisions were discontinued, and all are now published as one series of the Bureau. A list of the Bulletins issued in the present series follows.

Attention is directed to the fact that "the serial, scientific, and technical publications of the United States Department of Agriculture are not for general distribution. All copies not required for official use are by law turned over to the Superintendent of Documents, who is empowered to sell them at cost." All applications for such publications should therefore be made to the Superintendent of Documents, Union Building, Washington, D. C.

No. 1. The Relation of Lime and Magnesia to Plant Growth. I.—Liming of Soils from a Physiological Standpoint. II.—Experimental Study of the Relation of Lime and Magnesia to Plant Growth. 1901. Price, 10 cents.

No. 2. Spermatogenesis and Fecundation of Zamia. 1901. Price, 20 cents.

No. 3. Macaroni Wheats. 1901. Price, 20 cents.

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No. 5. Seeds and Plants Imported Through the Section of Seed and Plant Introduction for Distribution in Cooperation with the Agricultural Experiment Stations. Inventory No. 9, Numbers 4351–5500. 1902. Price, 10 cents.

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No. 7. The Algerian Durum Wheats: A Classified List, with Descriptions. 1902. Price, 15 cents.

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No. 9. The North American Species of Spartina. 1902. Price, 10 cents.

No. 10. Records of Seed Distribution and Cooperative Experiments with Grasses and Forage Plants. 1902. Price, 10 cents.

No. 11. Johnson Grass: Report of Investigations Made During the Season of 1901. 1902. Price, 10 cents.

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No. 21. List of American Varieties of Vegetables for the Years 1901 and 1902. 1903. Price, 35 cents.

[Continued on p. 3 of cover.]

FIG. 1.—METHOD OF INARCHING MANGO IN INDIA, USING TWO STOCKS.

FIG. 2.—SADDLE METHOD OF INARCHING MANGO, USED IN INDIA.

FIG. 3.—MANGO PLANTS FROM INDIA, SHOWING CONDITION ON ARRIVAL IN THE UNITED STATES.

U. S. DEPARTMENT OF AGRICULTURE.

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Beverly T. Galloway, *Chief of Bureau.*

SEED AND PLANT INTRODUCTION AND DISTRIBUTION.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., June 4, 1903.

Sir: I have the honor to transmit herewith, and to recommend for publication as Bulletin No. 46 of the series of this Bureau, the accompanying paper entitled "The Propagation of Tropical Fruit Trees and Other Plants."

This paper was prepared by Mr. George W. Oliver, an Expert of this Bureau, and has been submitted by the Botanist in Charge of Seed and Plant Introduction and Distribution with a view to publication.

The eight half-tone plates accompanying this paper are considered necessary to a complete understanding of the text.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

CONTENTS.

ILLUSTRATIONS.

THE PROPAGATION OF TROPICAL FRUIT TREES AND OTHER PLANTS.

INTRODUCTION.

The purpose of this bulletin is to furnish short notes dealing with the most feasible methods of propagating such tropical and subtropical fruit trees and other economic plants as have thus far received little or no attention in the United States and its near-by tropical possessions.

Considerable progress has already been made in introducing new and improved varieties of the fruits mentioned here, and experiments are being carried on with a view to simplifying the old methods of increasing the supply of these plants.

The seeds of many varieties of trees and other plants have been sown to produce fruiting specimens, notably the mango and the loquat. The result of this method of propagation has almost invariably been only a partial success with most of the subjects and wholly unsatisfactory with others.

Where seeds of any desirable fruit trees are available, they should, of course, be sown and the seedlings planted out in permanent locations when large enough; but these seedlings should only be used as stocks on which to bud or graft varieties of known value. In few cases can seedlings be depended upon for the production of fruit; the product is almost certain to be of inferior quality. Even if the parent tree be of a superior variety, seedlings are likely to revert to the original species. Therefore, as the seedlings of tropical fruits are as a rule of healthy and vigorous growth, their best use will be to supply a good foundation on which to work scions from good trees.

Other economic plants, such as tea and Manila hemp, have also been found to yield better products when propagated vegetatively than when grown from seeds. The hemp plant belongs to a division of the vegetable kingdom the members of which do not readily lend themselves to either budding or grafting, but it can be propagated quickly by other means of vegetative reproduction. The tea plant may also be multiplied vegetatively without resorting to budding or grafting.

As the propagation of most of the trees and plants dealt with in this paper can be accomplished by the use of but few of the methods of budding and grafting, only those methods which it is necessary to employ will be described in detail.

THE MANGO.

PROSPECTS AS A FRUIT TREE.

The Department of Agriculture is constantly in receipt of letters from present or prospective growers of the mango in the subtropical regions of the United States and its tropical possessions, asking for instructions as to the best method of propagating the finer varieties of the mango. Like most other fruit trees, it has been found that even when the seeds of good varieties are planted the fruit of the resulting seedlings is almost invariably inferior to that of the parent.

The mango will undoubtedly grow in popular favor. At present, unfortunately, it is suffering from a bad reputation, owing to the fact that the fruits which have been placed before the public in recent years have been grown mainly from seedling trees that are only fit to be used as stocks or wind-breaks. They are in fact wild or jungle mangoes and bear the same relation to the improved forms that the crab apple does to the Baldwin or Ben Davis apple. The prejudice which exists against them will, it is believed, disappear when the finer varieties become known. This will not be in a year or two, because there are comparatively few plants in the country which are worthy of growing, and so far as the writer is aware the fruit of only one of them has found its way North.

A short cut to success in raising a large number of trees of any approved variety is found in budding, or transferring a single bud, with a good-sized piece of bark attached, from a good variety to the stem or branch of a healthy stock plant raised from seed. In this way, from the growth made by the bud, exactly the same fruit is obtained as that produced by the tree from which the bud was taken. The stock on which the bud is inserted may be dwarf or tall; it may be vigorous or otherwise, and to the extent that these peculiarities occur in the stock it will, in a large measure, transmit similar peculiarities to the growth of the scion. But if the fruit of the stock should be of a fibrous nature and of an undesirable flavor, these characteristics exercise no influence whatever upon the fruit of the scion. Therefore nothing is gained by propagation from seed beyond perhaps the raising of new forms arising from artificially pollinated flowers or otherwise.

There is every probability that the finer varieties of Asiatic origin will soon be grown in the South much more extensively than heretofore. Not only has the Department of Agriculture had its agents on the lookout for improved varieties in India and elsewhere, resulting in several consignments to the Department greenhouses of many kinds reputed to be of great value, but a few private growers have also been importing some varieties which are highly praised. The acquisition by the United States of tropical possessions will render the cultivation of the mango of greater importance than ever. The fruit can not be imported from the Philippines, but it will be an easy matter to import young plants of the best of the many varieties growing there. In Porto Rico the tree thrives very luxuriantly and the fruit grown there can be landed in New York within five days; but there is a large tract of land in southern Florida where the mango thrives to perfection, and when once the growers become acquainted with the best methods of propagation, so that only the finest kinds shall be grown, the establishment of a large and profitable industry may be expected, for it is reasonably certain that the demand for mangoes of good variety will always keep pace with the supply.

PROPAGATION IN INDIA.

In India, the home of mango growing, propagation is effected by very crude methods, grafting by approach being the principal one. The union is made in several ways. Sometimes two stocks are planted close enough together so that a union may be secured on both with a single branch of a desirable variety. The method is shown in Plate I, figs. 1 and 3. Another method, shown in Plate I, fig. 2, consists in preparing the stock as in saddle grafting; an incision is then made in the thick part of a branch of the variety to be propagated, and this is fitted over the wedge-shaped top of the stock. The percentage of successful unions by these devices is said to be sometimes quite high compared with more rational methods, but the unions are never as satisfactory as could be desired. The young trees have to be supported by tying them to stout sticks, as there is danger of their being snapped off at the union by windstorms.

Grafting by approach or inarching has hitherto been the principal method of grafting in Florida and elsewhere in America, but for the reasons indicated above very little progress has been made in increasing the supply of first-class varieties.

PROPAGATING TESTS AT THE DEPARTMENT.

Numerous budding and grafting tests have been conducted in the greenhouses of the Department of Agriculture, beginning in the latter part of 1901 and continuing through the following summer. The trials were not as extensive as could be wished, owing to lack of good material. In spite of this drawback the results were not without value, and it is doubtful whether they would have been different had the trials been on a much larger scale. The experiments were inaugurated to determine the best wood for budding and grafting, because it is evident that one of the principal reasons for so many failures in the propagation of the mango is the use of the wrong kind of wood, especially for budding.

BEST AGE FOR WOOD.

It has been found that very indifferent results are obtained from wood which is less than a year old, but very satisfactory unions have been secured by the use of bud wood from branches from one to six years old. This is not to be wondered at, at least from the propagator's point of view, when we consider that the wood of the mango takes a longer time to mature than that of most of the fruit and forest trees of this country. The mango makes several distinct growths or "flushes" each summer; it will make a shoot with a number of leaves, then rest for a few weeks, when the terminal bud of the shoot will again start into growth. This is repeated in many instances as often as seven times before the close of the growing season. By midsummer, the wood of the first growth looks to the uninitiated as if it were much older than it really is, and this same wood is that which is commonly selected to give material for budding.

THICK BARK OF MANGO AN OBSTACLE IN BUDDING.

In connection with these experiments it was observed also that part of the difficulty experienced in budding the mango may be ascribed to the thickness of the bark, which does not allow a good union to be made by the usual methods employed in budding thin-barked trees. In shield-budding the mango, where the bark is raised on each side of the longitudinal cut in the stock and the bud inserted, there is too much air space left, resulting in almost every case in the death of the bud through the shrinking of the bark when not sufficiently supplied with moisture from the stock. The bark to which the bud is attached will shrivel to one-half its original bulk in a day or two. Decay will then almost certainly set in. In budding it is imperative that as close a fit as possible be secured on all sides, and that the parts be waxed and held firmly in place with a strong ligature until a union is effected. These details can only be carried out by giving very close attention to the work.

KNIFE FOR BUDDING THE MANGO.

The ordinary budding knife is not the best tool for the purpose of preparing buds and places for them. There are tools on the market for cutting and lifting sections of bark from stocks and scions which are more or less serviceable. A good device for this work can be easily made with two knife or razor blades, which should be firmly fixed in a piece of wood so that the edges will be apart from each other from an inch to an inch and a quarter. This instrument should be used for cutting through the bark of the stock and marking that of the scion, or vice versa, as it will be found that the bud with a section of bark attached will not fit tightly into the place made for it by the cutter. In the case where the section of bark has to be cut by a knife the marks will indicate just where it is necessary to make the section large, so that a tight fit will be secured.

METHODS WHICH SHOW BEST RESULTS.

In the course of the Department experiments the writer discovered that by the use of a method of attaching buds described in the seventeenth century the finer varieties of the mango, with skillful handling, may be propagated quite as easily as the peach or other fruit tree.

APPLYING THE BUDS.

Two or three-year-old seedlings and moderate-sized trees may be used as stocks on which to bud approved varieties of the mango. The stems selected for the reception of the buds should be at least an inch in thickness. When of this diameter, both wood and bark are thoroughly ripe, and the union of the scion with the stock will be easily accomplished if the operation of inserting the buds is performed carefully. The method of budding which has been found to work most satisfactorily (Pl. II, fig. 1) consists in removing a rectangular piece of bark from the stock and inserting a piece similar in shape and a trifle larger in size, having a bud in the center, from a branch of a desirable variety. This method of budding was described by Robert Sharrock in his History of the Propagation and Improvement of Vegetables, published in 1672.

The only departure from Sharrock's method of budding as used in the case of the mango at the present time is that the bud, instead of being taken from new growth, must be selected from wood old enough to have lost its foliage. This means that the bud wood will sometimes be over 2 years old. The use of bark of this age and even older insures success in budding the mango, as it unites rapidly with bark of a similar age on seedling stocks or on branches of trees. To a certain extent success depends upon the precision with which the section of bark is removed from the stock and also from the variety to be propagated, as the more neatly the bud section is fitted into the space prepared for it the greater the probability of a successful union.

After the section of bark from the bud stick is nicely fitted in place, and before tying, a small quantity of grafting wax should be smeared over the parts where they come together and tied firmly in place with thick strands of raffia (Pl. II, fig. 1, C). This effectually prevents the admission of air to the spaces which, no matter how carefully the operation be performed, exist between stock and scion; it also serves to prevent moisture from gaining access to the cut surfaces. The cut surfaces and all but the bud should then be covered with strips of cloth dipped in melted paraffin, wrapping being begun at the lower part, so that when finished water will not gain entrance to the wrapped section of bark. If that part of the stock where the bud is tied be exposed to the sun, it is always advisable to furnish shade, which is best supplied by strips of paper tied above the bud and extending down over it. Two weeks may be allowed to pass before an examination is made. The cloth wrappings may then be removed and the raffia should be loosened if there is danger of its cutting into the bark. When a sufficient time has elapsed to make certain that a union has taken place, part of the top of the stock should be removed in order to encourage the bud to start. This it will do with very little coaxing.

When sufficient growth has been made, all of the stock above the bud may be removed and the cut part coated with liquid grafting wax or tar to exclude moisture and prevent rotting.

WHEN TO BUD.

Budding may be performed at any time during the growing season, but with each plant there are certain periods when the operation will be found to be more successful than at other times. These periods are indicated by the growths or "flushes" being about half developed. At these times the sap appears to be more active than at others, as the bark peels from the wood more readily than when the growths are of firmer texture.

SELECTION OF BUDDING MATERIAL.

This part of the operation is of the utmost importance because success depends to a great extent upon the use of proper buds. Many growers who have tried to work buds of good varieties on seedling stocks are under the impression that the operation is an exceedingly difficult one, but this idea has arisen from the fact that the work has been prosecuted in a manner contrary to the demands of the structural details of the plant.

The mango is not the only tree which does not take kindly to young buds; in fact its propagation as carried on at the Department of Agriculture was suggested to the writer during some experiments in the propagation of the pecan by budding, as described in Bulletin No. 30 of the Bureau of Plant Industry. As has already been stated the 1-year-old wood of the mango is quite immature and comes far short of furnishing the best buds for propagation; therefore wood under this age should not be employed for budding if other material can be had.

A SECOND METHOD OF ATTACHING THE BUD.

Another method of attaching the bud varying slightly in the details from that given above has been practiced during the past season at Miami, Fla., with an encouraging degree of success. This method is shown in Plate II, fig. 2. The bud section differs from the rectangular-shaped piece of bark in that one end of it is pointed instead of being cut straight across, which makes it possible to push the bark of the scion down tight against the bark of the stock; the top part is then cut off square with the transverse cut in the bark of the stock, and is pressed firmly into position previous to tying and waxing in the usual way.

RAISING SEEDLING STOCKS.

The mango does not readily lend itself to propagation by cuttings on account of the green or immature condition of the shoots while the wood is still small in diameter. The writer has tried several batches of cuttings under varied conditions but always with poor success; they invariably callus well, but roots are slow to form, and when a cutting does produce a root it is usually a single fiber of so small and brittle a nature that the rooted cutting is difficult to transplant from the sand bed into pots or to the open ground.

It is necessary, therefore, to have recourse to seeds for the purpose of supplying plants to use as stocks for budding. The seeds should be sown very soon after being taken from the fruit, as they lose their vitality shortly after the fruit is ripe. Especially is this the case when the seeds are allowed to dry for a few days. The seed of the mango resembles that of the orange in that it often contains several embryos. Out of a batch of several hundred seeds sown in the Department greenhouses during the past season it was common to find instances where from two to five, and in a few cases no less than eleven, seedlings were produced from single seeds. Plate III shows eight plantlets all springing from one seed. This condition is not desirable, however, as in those cases where more than one or two seedlings sprout from the same seed they are usually of weak growth, and it is questionable whether they should be grown, especially when seeds are plentiful.

From the time the seeds are sown until the plumules appear above ground, the seed boxes or beds should be out of the reach of heavy rains, as the subterranean seed leaves are liable to rot when the soil is kept wet for any length of time.

When shallow garden flats are used in which to raise the seedlings the roots are under better control for future planting than if they were sprouted in beds or frames. An excellent medium in which to sprout the seeds is half-decayed leaves. A layer of leaves 1 inch thick is placed in the bottom of a flat; on this the seeds are deposited at sufficient distances from each other to cover less than half the space. About an inch of half-decayed leaves is then placed over the seeds and pressed down firmly, the sowing being completed by slightly dampening the surface with a sprinkler.

If the surface layer of rotted leaves becomes dry at any time a gentle watering should be given, taking care not to soak the contents of the boxes. It is undoubtedly a safe plan to keep the contents of the boxes rather dry than otherwise during the sprouting period.

TRANSPLANTING YOUNG SEEDLINGS.

Germination is somewhat irregular; the first sprouts will appear in three or four weeks after sowing, but others will continue to appear for several weeks later. Nothing is gained, rather the reverse, by transplanting the seedlings when quite young; it is best to wait until the leaves of the first growth change from reddish brown to dark green. The seedlings can then be transplanted without wilting.

By the time the leaves of the seedlings reach a deep-green color a considerable quantity of roots will have formed which are capable of being removed from the flats without much injury, and if proper care is exercised in those cases where there are several plantlets from the same seed they may be disentangled successfully. Strong seedlings may go directly into 4-inch pots. Deep bamboo pots are much to be preferred when available, as owing to their greater depth there is less danger of the roots becoming matted while in the pots.

Immediately after the potting comes the crucial period in the life of the seedling, because there is danger of the leaves flagging, through the loss of a great deal of sap at a time when the roots are not in a condition to replace it. Therefore, until the roots gradually recover, it is advisable to keep the plants in a shaded house or frame and at the same time to supply a fairly humid atmosphere.

There is no necessity for keeping the young plants in pots for a long period. When the second or third growth has been made and hardened considerably, the new roots will have taken sufficient hold of the soil to insure the successful growth of the plant after it has been set out in its permanent position.

The soil to be used in potting should consist of fibrous loam, with sand and leaf mold in small quantities. In potting, the soil should not be rammed very firm for fear of bruising the roots, which are unusually tender. While the seedlings are in the pots watering will have to be performed as carefully as when in the seed boxes, to prevent souring of the soil and the consequent rotting of the roots.

IMPORTING MANGO SCIONS.

Scions of the improved varieties of the mango cost much less than plants to import from India and elsewhere in the Orient, but as a rule they arrive in the United States in an unsatisfactory condition. With the purpose of ascertaining the most favorable methods of packing, Messrs. Lathrop and Fairchild, the agricultural explorers, recently sent several tin cases of scions of the Jaffna mango to the Department and the results obtained are of considerable importance for the guidance of intending importers. The batch of scions forwarded from Colombo, Ceylon, on April 6, 1902, and received at the Department May 5, consisted of four cylindrical tin tubes. One case contained bud sticks each less than three-quarters of an inch in diameter, the ends of all being covered with collodion. The bud sticks were afterwards dipped in clay mud, which formed a very tenacious covering. These scions were packed with a small amount of moist coir, and arrived in fairly good condition, although they were comparatively young growths. The same method of forwarding could probably be successfully applied to older wood, which has been proved to be of much greater service in budding operations.

Another case contained scions, half of which were wrapped in tin foil and the other half without wrapping. All were coated with collodion on the cut surfaces and packed in pure, fresh, moist sawdust. The contents of this box were almost dead when opened, those scions which were wrapped in tin foil showing more signs of life than the others. The scions in the third case were treated similarly to those in the second box, except that the packing material was moist coir instead of moist sawdust, plenty of air space being provided. These scions were in an advanced stage of decomposition. In the fourth lot the scions were wrapped in tin foil and packed in moist sawdust mixed with powdered charcoal. In this instance all were dead.

THE LOQUAT.

REGIONS WHERE THE LOQUAT MAY BE GROWN.

The loquat (*Eriobotrya japonica*) is a native of Japan and China. Its possibilities as a fruit tree have long been known in the South, where it is capable of being grown to perfection in several States. Young plants have proved hardy during mild winters at Washington, D. C., but when the temperature falls to zero and remains so for any length of time the plants are injured permanently. As the flowers of the loquat are produced during the autumn months, both flowers and fruit are likely to be injured by cold; for this reason there is little probability of the loquat being grown for fruiting purposes in regions where severe frosts are frequent.

However, there is a large tract of territory where the fruit may be successfully produced in this country. From Charleston south along the coast belt, in the Gulf States, and in California south of the thirty-eighth parallel it is quite hardy, and in some parts of New

Mexico and Arizona it will probably be found to thrive. In several States it ripens very large crops of fruit. Its period of blooming extends from September till frost, according to variety and location; the fruit ripens in spring.

In the more temperate regions many trees have been planted; most of them, however, are of seed origin, and it may confidently be said that were they of the finer varieties such as are cultivated in some parts of the Old World, the fruit would be more appreciated throughout the country. The trees at present in cultivation may be put to a very good use; they can be very easily worked with new varieties, as the loquat is one of the easiest subjects with which the propagator has to deal.

The agents of this Department have of late been assiduous in collecting new or little-known varieties, principally from the Mediterranean region, but also from China and Japan, and there are now in the Department greenhouses several kinds of great promise, from which a considerable quantity of bud wood may be distributed. Some of these varieties are said to be nearly seedless, a characteristic much to be desired, as the seeds are ordinarily quite large and occupy a considerable portion of the fruit.

RAISING SEEDLING STOCKS.

In a favorable climate the loquat bears heavy crops of fruit annually, and so gives an abundant supply of seed from which to raise plants to use as stocks for the reception of buds and grafts of the improved varieties. It will be found that when a tree sets a large quantity of fruit, a certain proportion will, within a short period, attain medium size and change color suddenly. These fruits, however, are almost tasteless, there being very little pulp in them; but the seeds are invariably good, and from the fact of ripening early they will, if sown as soon as gathered, produce larger plants by the end of the growing season than the seedlings raised from seeds which ripen later. As young loquat plants, budded or otherwise propagated, are not so difficult to transplant as are the great majority of evergreen trees, there is little necessity for pot cultivation, as the work of propagation can be performed in the open air without encountering any serious difficulty. The seeds should be sown an inch deep, about 6 inches apart, in rows distant from each other from 2 to 3 feet, to allow horse cultivation and to give an abundance of space for the operator to work when budding. After sowing, the ground should be covered with an inch or two of long stable litter, or any other material which will shelter the ground from the sun and at the same time be easily removed when the sprouts appear through the soil. At this period very careful cultivation is necessary, as it is imperative that the surface soil in the immediate vicinity of the young plants should be kept loose.

The seedlings will not make sufficient progress to permit budding operations during the first season, but by midsummer of the season following they will have attained sufficient size of stem for the buds to be attached with ease. They have been found after many trials to unite best by the common shield method. Plate IV, fig. 2, shows a 3-year-old stock budded two years.

Buds should be selected from well-ripened branches of small diameter, as these are easier to insert than buds taken from young succulent growths. The bark on 1 or 2-year-old seedlings is quite thick and easily bruised, and does not lift well; therefore, when buds from thick and succulent wood are used there is always difficulty in placing them under the bark of the stock. It will be found, moreover, that the buds in the axils of the fully developed leaves are exceedingly small and the bases of the petioles very large; consequently, buds of this nature are far from being the best with which to work. The loquat, as has already been hinted, is an exceedingly easy subject to propagate by budding or grafting. The buds, if properly inserted at a time when the bark lifts freely, will unite within two weeks, and a week or two later, if that part of the stock above the inserted bud is partly cut back, the buds will begin to grow very rapidly. The first indication of growth consists in one or two tiny leaves covered with light hairs. Shortly after these appear the top of the stock may be pruned to within an inch or two of the inserted bud, leaving only one or two mature leaves for a time.

Propagation by grafting is not commonly practiced. When comparatively large branches are headed back and scions inserted, the resulting unions are often unsatisfactory, being likely to be broken off by windstorms. A method of side grafting 6-months-old seedlings is shown in Plate IV, fig. 3. This method is very satisfactory and can be used best on seedlings grown in pots for shipping purposes.

THE FIG.

CUTTINGS.

The usual method of propagating the fig is by means of cuttings of the 1-year-old shoots. These cuttings are made in lengths of from 8 inches to several feet, according to the moisture in the soil. When the cuttings are not intended to be transplanted and are placed in the orchard to form trees, large-sized cuttings of 2-year-old wood are used, but when they are placed in nursery rows shorter lengths are usually selected, thus facilitating handling in transplanting or shipping. Where short cuttings will succeed, a length of from 8 to 12 inches will be found ample, the ends of the 1-year-old shoots giving most satisfaction, as the subsequent growth is, as a rule, straight and strong.

The best time to make the cuttings is in the fall when the season's growth is thoroughly ripe. Where the winters are not severe the cuttings may be put in the ground where they are to root. They are most easily cared for when placed in rows moderately close together, so that the young plants can be watered if necessary and cultivated with less labor than if put in the positions which the trees are intended to occupy permanently. In localities where the cuttings are likely to be injured by freezing weather they should be prepared in the fall and stored during the winter in moderately damp sand in a cellar. In early spring, or as soon as the soil is in a workable condition, trenches should be prepared for the reception of the cuttings, as they are likely to make roots very early.

In preparing the cuttings the usual custom is followed by making the lower cut just beneath a joint and where a terminal bud is not present the upper cut should be made about three-quarters of an inch above a joint. The soil must be deeply worked and the cutting inserted in the soil so that only the top bud is visible.

GRAFTING AND BUDDING.

Propagation by grafting and budding is sometimes resorted to, especially when trees prove to be unprofitable and it is desired to use them as stock plants on which to work good varieties. Another reason why budding and grafting may be practiced more than hitherto is that Smyrna and Capri figs may be worked on other varieties of old-established plants, and thus come into bearing much sooner than when raised from cuttings.

The successful colonization of the insect which pollinates the flowers of the Smyrna fig will result in greatly enlarging the fig-growing industry not only in California, but also in several other sections of the country, if the insects can be established and maintained through freezes.

Although the fig is not so easily propagated by the usual methods of grafting and budding as are most of the other kinds of fruit trees, yet there are several ways of accomplishing the desired result. In Bulletin No. 9 of the Division of Pomology of this Department Dr. Gustav Eisen describes a method of grafting the fig employed in California. This is a modification of the cleft graft, which is used mainly on branches of large diameter and is successful when skillfully done. It differs from ordinary cleft grafting in that the cuts for the reception of the scions do not point to or cross the pith, but are directed to one side. The operation must be performed when the trees are in a dormant condition.

An exceedingly simple method of grafting which may be used by a person having little experience in this line of work has been successfully practiced at the Department of Agriculture for some time.

This method consists of preparing the stock for the reception of the scion as in shield budding. This is done by making a transverse cut through the bark three-quarters of an inch in length. From the middle of this incision another cut is made toward the main stem or root for fully an inch. The bark is then prized up as seen in Plate V. D. Instead of inserting a single shield bud, a small twig having one terminal and one or two lateral buds is used (Pl. V, A. B, C). The scion is prepared as follows: A long scarf is made at one side through the pith and a thin piece of the bark on the reverse side is removed. With the long cut facing the stock the scion is pushed deeply into the place prepared for it (Pl. V, E) and is tied firmly with raffia. The corners of the bark of the stock are brought close to its own stem and bound firmly in that position (Pl. V, F). Melted grafting wax should then be put on, or narrow strips of waxed cloth may be applied instead, to exclude air and moisture. If possible, the scions should be selected from branches not over one-half an inch in diameter when they can be found of sufficient firmness of that thickness. Small lateral shoots having a terminal bud and only an inch or two in length and quite thin will unite by this method very easily. It is not necessary for the scions to be dormant, but they should be fully matured and the leaves cut off to about one-half inch from the buds. The bark slips readily from the time growth begins in spring, so that the operation may be performed at any period during late spring and summer.

In the course of about two weeks after the operation is performed, if the scions remain fresh, the probabilities are that a union will have been effected. Part of the top of the stock may then be removed to induce the scion to start growth, and when it has made some headway the top of the stock may be cut off near the scion.

Seedlings are well suited to this method of propagation for use as stocks, as the bark near the ground line is quite thick and lends itself readily to scion budding. The seedlings should be at least 2 years old. At this age that part of the stem near the collar is much greater in diameter than will be found a few inches above, thus allowing a good-sized scion to be inserted.

TEA.

NECESSITY FOR VEGETATIVE PROPAGATION.

Dr. Charles U. Shepard, of Summerville, S. C., whose successful tea-growing experiments entitle him to rank as the highest authority on this subject in America, has concluded that future plantations of some of the varieties now grown and which have been raised from seed must be propagated vegetatively because of the important fact that some of the individual plants in a batch of seedlings show great superiority over others in several of their characteristics, as for instance, in leaf production and in the quality of the product. In other words, seeds can not be relied upon to reproduce the exact characters of the parent plant. Dr. Shepard also finds that some forms which produce superior teas have very poor roots, thus necessitating grafting upon stronger-rooting varieties.

The propagation of the desirable varieties of the tea plant may be secured in several ways according to the object to be attained. For instance, grafting should be the method chosen in cases where a desirable variety has a poor root system; because by taking young plants of varieties known to form good roots and using them as stocks the poor-rooting kinds may be united to them by means of the veneer method of grafting. Again, the stock of desirable plants of any particular variety having good root systems can be increased by layering, if the plants have previously been prepared by pruning so as to provide suitable wood for the purpose.

The quickest and least troublesome method of propagation is by cuttings of the newly ripened shoots (Pl. VII, figs. 1 and 2). None of the above-named operations is difficult, but to perform any of them successfully requires constant care and attention to the details while the scions are uniting with the stocks or when the branches and cuttings are forming roots. Sometimes, in layering operations, the weather supplies conditions which enable the branches to root without further care on the part of the operator; but not so with grafts and cuttings, as these operations must be carried on under conditions which require continual care during the period required for uniting or for rooting. Any neglect at this time is certain to result disastrously.

VENEER GRAFTING.

Seedling stocks may be grown in 4 or 5-inch pots for the reception of scions by the veneer method of grafting. To have the plants in perfect condition for working, it is necessary that they be grown from the seedling stage without a check, as the healthier the plant the better the chance of a successful union. Another important matter in this connection is that the stock plants should not be allowed to form matted roots in small pots; therefore, it will be found better to lift them from the nursery and put them in pots previous to the operation; or they may be grown and grafted while in garden flats. If this last-named method is chosen the plants should be situated far enough apart in the flats to be easily handled. If the grafting is performed while the stocks are in active growth, the union will take place more quickly than when the plants are in a dormant condition. The operation should be performed in the early part of spring. Plate VI, A, shows how the incision in the stem should be prepared. This should be made with a sharp knife and the cut at the deepest part should not be more than one-third of the diameter of the stem. The scion (Pl. VI, B) must be shaped at the base so that it will fit neatly into the place prepared for it on the stock. It should then be tied as seen in Plate VI, C, and afterwards a small quantity of sphagnum moss should be tied over the part where the stock and scion come together, as shown in Plate VI, D.

Immediately after the operation is performed as above described, the plants should be placed in a close, shaded propagating frame and kept there until the union is effected; this will take place in a few weeks. The temperature of the frame should be kept uniformly at from 60° to 65° F. If a layer of moss be put under the pots and the contents of the frame syringed occasionally a favorably humid atmosphere will result. Where greenhouse accommodations are not available for the propagating frame a hotbed may be built out of doors in a location where the sun will not have much effect in raising the temperature. From 6 to 9 inches of stable litter and leaves will provide ample heat during the spring. When it is found that the scions have made connection with the stocks, air should gradually be admitted to the frames. Shortly after this the tops of the stocks may be cut off close to the scions. Planting out may be deferred till the scions have made their first growth.

HERBACEOUS GRAFTING.

Another method which the writer has tried successfully is herbaceous grafting. This consists in removing the top from a seedling when a few weeks old, making a clean, straight cut through the stem above a bract or a leaf, much in the same way that coffee seedlings are treated for grafting, but with this difference: In the case of the coffee the very large cotyledons persist for many months after germination and, being well above ground, they perform the functions of true leaves, so that when the plumule is severed grafting is performed with ease and the seedling receives only a very slight check. But with tea the cotyledons are underground, and although they also persist for a considerable time the plumule can not be removed with the same degree of safety as with coffee. Therefore it is best to remove the top above a bract or leaf. A cut is then made through the stem, as for cleft grafting, and the base of the scion is cut to a wedge shape, so as to fit nicely into the stock. It is kept in place by wrapping with thin strands of raffia. It will be found easiest to perform this operation when the seedlings are in flats, as then they occupy less room than when in small pots. It is necessary for all grafted plants to be kept in a close and shaded frame while the scions are uniting with the stocks.

PROPAGATING HOUSE.

In preparing for cuttings, a cool propagating house is the first requisite. It should be a lean-to structure and so built that the slope will face the north. The interior may be about 8 feet wide. This space will be ample for two benches, each 2 feet 9 inches wide, one on each side of a central path, 2 feet 6 inches wide. The heating apparatus should be sufficient to keep the sand at a temperature of 60° F., and the temperature of the house should not fall below 50° F. At all times a humid atmosphere should be maintained. During bright sunshine the glass should be shaded. One way to accomplish this is by lengths of cloth fixed on rollers. There is, however, always danger of neglecting to lower the cloth at the proper time, so that the safer plan would be to put on a permanent shade by painting the glass with white lead and turpentine. The benches should be constructed at a height of about 3 feet from the floor, and the uprights so made that the pipes may be boxed in, leaving a small door, provided with leather hinges, at intervals of 8 or 10 feet to supply the necessary heat to the house during extra cold weather. The bottom of the bench should be of wood, 2-inch planks being the preferable size, one-quarter inch spaces being left between the planks for drainage. Four inches of clean sand will be ample. Previous to putting in the cuttings beat the sand firmly with a piece of 4 by 4 inch scantling. The beds are then ready for the cuttings.

CUTTINGS.

The cuttings of the tea plant take a long time to root, and consequently it has been found that the most propitious season for rooting is during the winter months, the cuttings being put in the sand any time during the month of November.

The best wood to use for the cuttings is a moderate-sized branch of the current season's growth taken from a plant the leaves of which have not been picked over within the previous six months. As many branches should be cut at one time as will make about 500 cuttings, the leaves being dampened with a sprinkler as soon as they are brought indoors and the cuttings made before the leaves have an opportunity to dry out. They may be made into lengths of from 4 to 5 inches (Pl. VII, figs. 1 and 2), as cuttings longer than that are not so certain to root. A medium-sized shoot will make several cuttings. The terminal part of the shoot may be used if the wood is firm or well ripened. At least two leaves should be left on each cutting, and if the leaves are quite close together several may be left. The reason for leaving only a few leaves is that the nearer they are to the surface of the sand the better the chance of the cutting to root, as the moisture condenses on the under surface of the leaves, thereby keeping the cutting in a crisp and fresh condition until the roots are formed. Plate VII, fig. 2, shows two cuttings ready to be put in the sand. In putting in the cuttings the propagator will usually find it most convenient to work from left to right. The necessary tools are a dibble, a flat piece of board 2 inches in width and as long as the bed is wide, and the sand beater already mentioned. The piece of board should be placed 2 inches from the end of the bed and a line drawn with the dibble close to the board across the bed: this will mark the position which the first row of cuttings is to occupy. Each cutting should be put in with the aid of the dibble, first making a deep hole with the instrument; then the base of the cutting should be put into it as far as it will go, allowing the bottom leaf or leaves to rest on the sand and pressing the sharp end of the dibble once or twice down into the sand close to the stem of the cutting, firming it in its place. By this operation the cutting should occupy a space of about 2 inches each way. When a row is put in the sand the board should be placed as close to it as it will go and two or three sharp taps given it with the sand beater, which will still further help to firm the cuttings; then the work should proceed as before. When a batch of cuttings is put in, enough water should be given through a large sprinkler to settle the sand around the bases of the cuttings. After the beds are filled the subsequent treatment should consist of frequent slight syringings in preference to heavy watering at any one time. The atmosphere should never be allowed to become dry. During periodical spells of warm weather the heat should be turned off and a little air given, but not enough to cause drafts in the house.

MANILA HEMP.

IMPORTANCE OF INTRODUCTION INTO THE UNITED STATES.

The plant which yields the fiber known as Manila hemp is a species of banana (*Musa textilis*). It is indigenous to the Philippine group and other Pacific islands south to the Moluccas. The hemp-growing industry is conducted almost exclusively in the Philippines, as in some parts of the islands the climate is perfectly adapted to the growth of the plant, its principal requirements being a moderately high temperature and a well-drained, moist soil. The Manila hemp grows to a height of 20 feet, and requires at least 3 years to reach the stage which is best for the production of the fiber.

It may be mentioned here that what is commonly called the trunk of the banana plant is not really a trunk, but merely a continuation of the leaf stalks, the outer ones folding over or clasping the inner ones in such a way that a trunk-like formation is the result. The fiber is found in this trunk-like body and is harvested shortly after the plant comes into flower.

In the recently issued Pronouncing Gazetteer and Geographical Dictionary of the Philippine Islands it is stated that nearly 100,000 long tons of Manila hemp are annually exported from the Philippines, chiefly to the United States and England. The first grade of fiber from 1885 to 1894 ranged in price per kilogram (2,204 pounds), between $6 and $17.12. The inferior grades were 25 to 40 per cent lower in the Manila market. The Gazetteer states that under existing conditions, abaca Manila hemp plantations in the Philippines with careful management yield an annual return of 30 per cent on the investment, which indicates what may be expected from successful hemp plantations in the near-by tropical possessions of the United States.

The introduction of the Manila hemp plant into the United States has been attempted several times, but without success until recently, when a supply of seed was received at the Department of Agriculture from the insular bureau of agriculture of the Philippines.

RAISING PLANTS FROM SEEDS.

The plant is exceedingly easy to increase by dividing the underground stems, but in order to get a supply of plants for this purpose propagation by seeds has, of course, to be resorted to.

As the seeds received from the Philippines have been successfully germinated, an account of the means by which this result was secured may be of value to those who contemplate raising a stock in this way. The seeds were gathered in the Islands as soon as ripe, mixed with finely powdered charcoal, and shipped to Washington in small cylindrical tin tubes. A period of about forty days thus occurred between the time of gathering and the time of sowing. As it has been thought that the seeds lose their germinative power in less time than this, owing to their failure heretofore to germinate in this country, some of the seeds were kept and sown at intervals of from one to six weeks. The percentage of germination was high in every case, and, although it has not been ascertained just how long the seeds will retain their vitality after ripening, it would seem that the methods formerly used to germinate them were faulty.

These seeds were sown in garden flats filled to within an inch of the surface with clear, large-grained river sand, upon which the seeds were scattered, pressed down firmly, and covered with one-half inch of sand. A sheet of glass was placed over the box and the sand kept at a temperature varying from 75° to 80° F., the lower temperature occurring during the night. Only one slight watering was given before germination. In fourteen days after the seed was sown the plumules gradually made their appearance, and in three weeks more the plantlets were large enough to go into small pots (Pl. VIII). To give them favorable greenhouse treatment in this latitude, the glass during autumn should be without shade and the temperature of the house 60° F. by night and 20° higher during the day.

In the island of Porto Rico, where it is intended to start plantations, the seeds may be sprouted with the aid of a frame and sash, but it is evident that a slight bottom heat should be maintained, especially during the sprouting period. This will be most easily supplied by a layer of stable manure, mixed with leaves, to the depth of a few inches. Over this some ashes should be placed, packing the mass very firm. The bed should then be finished off with sand to a depth of 2 inches. The seedlings will make considerable growth in pure sand, and it would perhaps be advisable to transfer them previous to permanent planting, when they attain a height of from 2 to 4 inches, to nursery beds of well-prepared soil. As an alternative, the seedlings, after being exposed to the maximum amount of light and air while in the seed bed for a period of two or three weeks, may be planted out in their permanent quarters during cloudy or even wet weather; that is, if the nature of the soil will permit it. Well-drained soils with an abundance of humus in their composition will not offer any great obstacle to planting even in wet weather, and the plants will certainly benefit by this treatment.

CULTIVATION IN THE PHILIPPINE ISLANDS.

In a paper entitled "La culture de l'abaca aux Philippines," by De Berard, published in L'Agriculture Pratique des Pays Chauds, 1901, an account is given of the propagation of the Manila hemp by seeds and its cultivation in the Philippines. The author names the following varieties grown in the isle of Luzon: Moro Blanco, Moro Negro, Moro Colarado, Turnean ou Mosqueado, Tagacan Blanco, Tagacan Colarado, Bagacayan, and Samina.

With respect to the climate, it is stated that in order to reach the maximum production there must be considerable humidity. The limit of altitude for cultivation is given at from 300 to 400 yards. The plants are said to be partly grown in the shade of trees having open branches and light foliage, but not near enough to let the roots interfere with those of the bananas. The fiber from plants grown in dense shade is finer and longer, but less strong, than that from plants grown without shade; however, the fiber which combines fineness, length, and strength commands the highest price. The land described as best suited for the plant consists of moist but well-drained volcanic soil, mixed with vegetable humus. It is stated that the method by which the hemp plant is propagated in Albay and in South Luzon, where the best fiber is produced, is by seeds and also by division of the underground stems. The last method is generally preferred by cultivators, as it entails less work and produces better results. The collecting of seeds is carried on in a careless way by the cultivators of the many small plantations, resulting in great irregularity in the quality of the product, owing to the mixing of strains or varieties in the same plantation. In raising the seedlings it is said that previous to sowing, the seeds are soaked in warm water for several hours, washed, and dried in the shade, then sown two together in prepared holes from 5 to 8 inches apart, and covered with fine soil to a depth of three-fourths of an inch. The beds are then covered with a light layer of straw, which is set on fire. This last operation has for its object the hastening of germination. The beds are watered very lightly for several days, always before sunrise. Only enough water is given to make the soil moist on the surface. If the nursery is exposed to the full sun, shade is provided, but only during the warmest part of the day. After fourteen or fifteen days the seeds begin to germinate, and when the seedlings reach a height of from 2½ to 3 feet they are transplanted to well-prepared soil at a distance of from one-half to 2 yards apart and watered only until established.

PLATES.

DESCRIPTION OF PLATES.

Plate I. Fig. 1.—Method of inarching branch of improved variety of mango, used at the present time in India. Two seedling stocks are planted so that their stems grow side by side; a single branch is then inarched to the two stocks. When the union is complete the branch is severed from the parent tree. Fig. 2.—Saddle method of inarching mango on seedling stocks, used in India. Although an unsatisfactory method of propagation this gives a better union than that shown in fig. 1. Fig. 3.—Mangoes propagated in India, showing their condition upon arrival in the United States.

Plate II. Fig. 1.—Rectangular patch method of budding the mango. When stocks of at least 1 inch in diameter are used this method has given the best results in the greenhouses of the Department of Agriculture. Fig. 2.—A method of budding used with considerable success in Florida. Fig. 3.—Budded mango seedling, showing first and second growths from an inserted bud. In order to induce the bud to start the stock is headed back about 1 foot above the bud. When two growths have been made, the stock is cut back close to the bud.

Plate III. Germination of mango, showing eight plantlets springing from one seed. One-half natural size. The stage of development shown in the illustration occurs about six weeks after planting the seeds.

Plate IV. Fig. 1.—Crown grafting the loquat on tall stocks, showing a bad union. Fig. 2.—A 3-year-old loquat stock, budded two years, showing a good union. Fig. 3.—Side grafting the loquat, 6-months-old seedlings being used as stocks. A, scion inserted; B, scion inserted, tied, and waxed; C, scion united and growing and stock cut back.

Plate V. Scion budding the fig. A, B, C, scion prepared for inserting; D, bark raised ready for the reception of the scion; E, base of the scion inserted under the bark of the stock; F, scion inserted and tied.

Plate VI. Veneer grafting the tea on 1-year-old seeding stocks. B, scion ready for placing in position in incision on stock shown at A; C, scion inserted and tied with raffia; D, small quantity of damp sphagnum moss tied around the stock and scion.

Plate VII. The propagation of the tea by cuttings of the ripened wood. Fig. 1.—Cuttings ready to be placed in sand. Fig. 2.—Rooted tea cuttings ready to be placed in soil.

Plate VIII. Manila hemp. Six-weeks-old seedlings showing seeds still attached to the plants. Natural size.

O

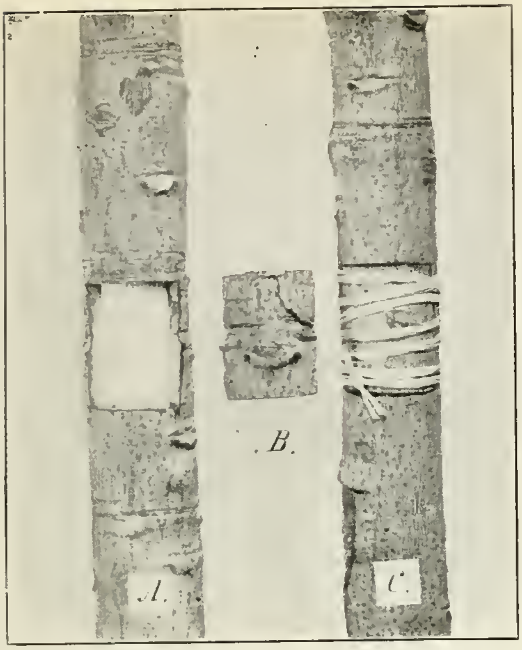


FIG. 1.—RECTANGULAR PATCH METHOD OF BUDDING THE MANGO.

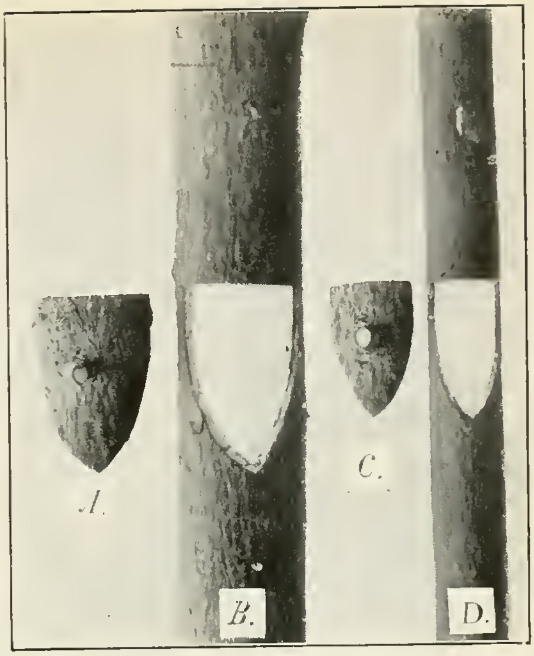


FIG. 2.—METHOD OF BUDDING THE MANGO USED IN FLORIDA.

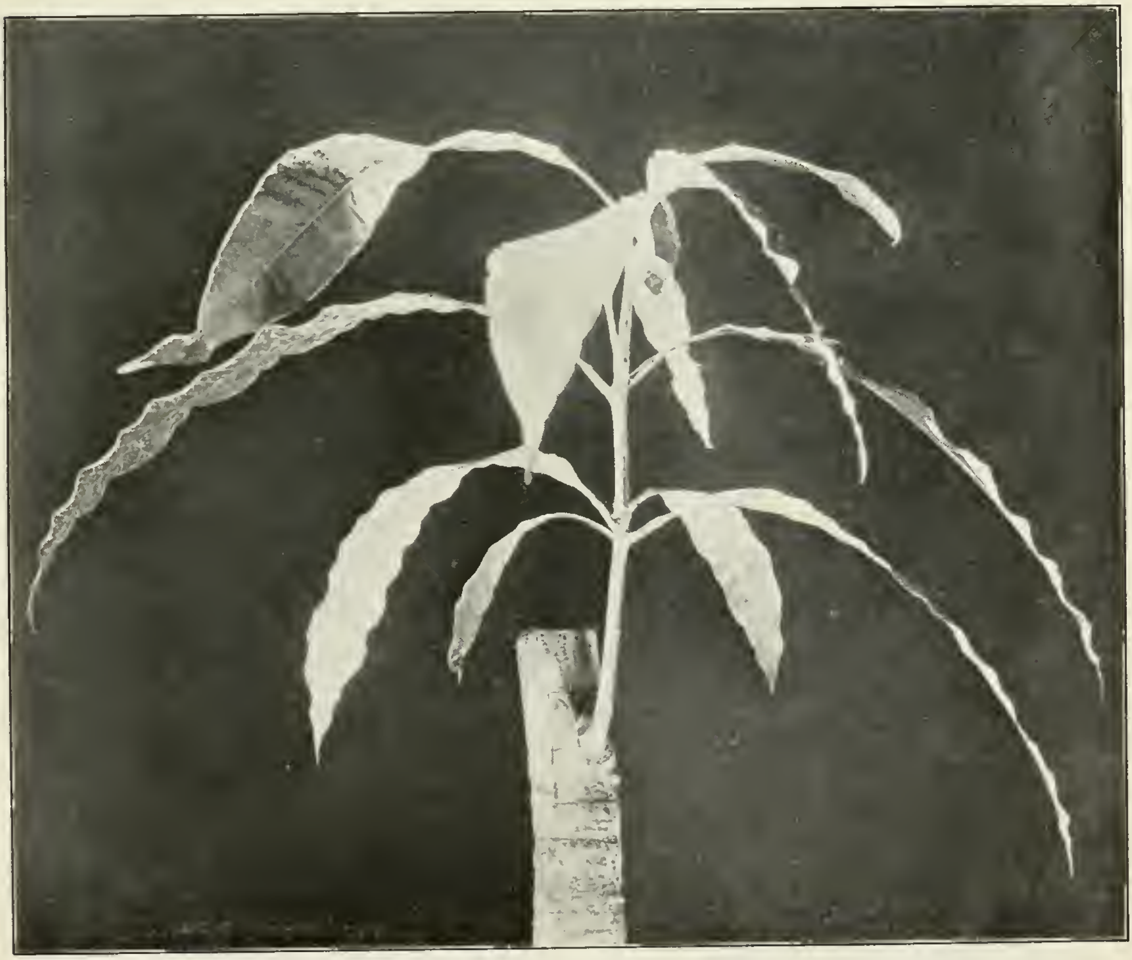


FIG. 3.—BUDDED MANGO SEEDLING, SHOWING FIRST AND SECOND GROWTHS FROM INSERTED BUD.

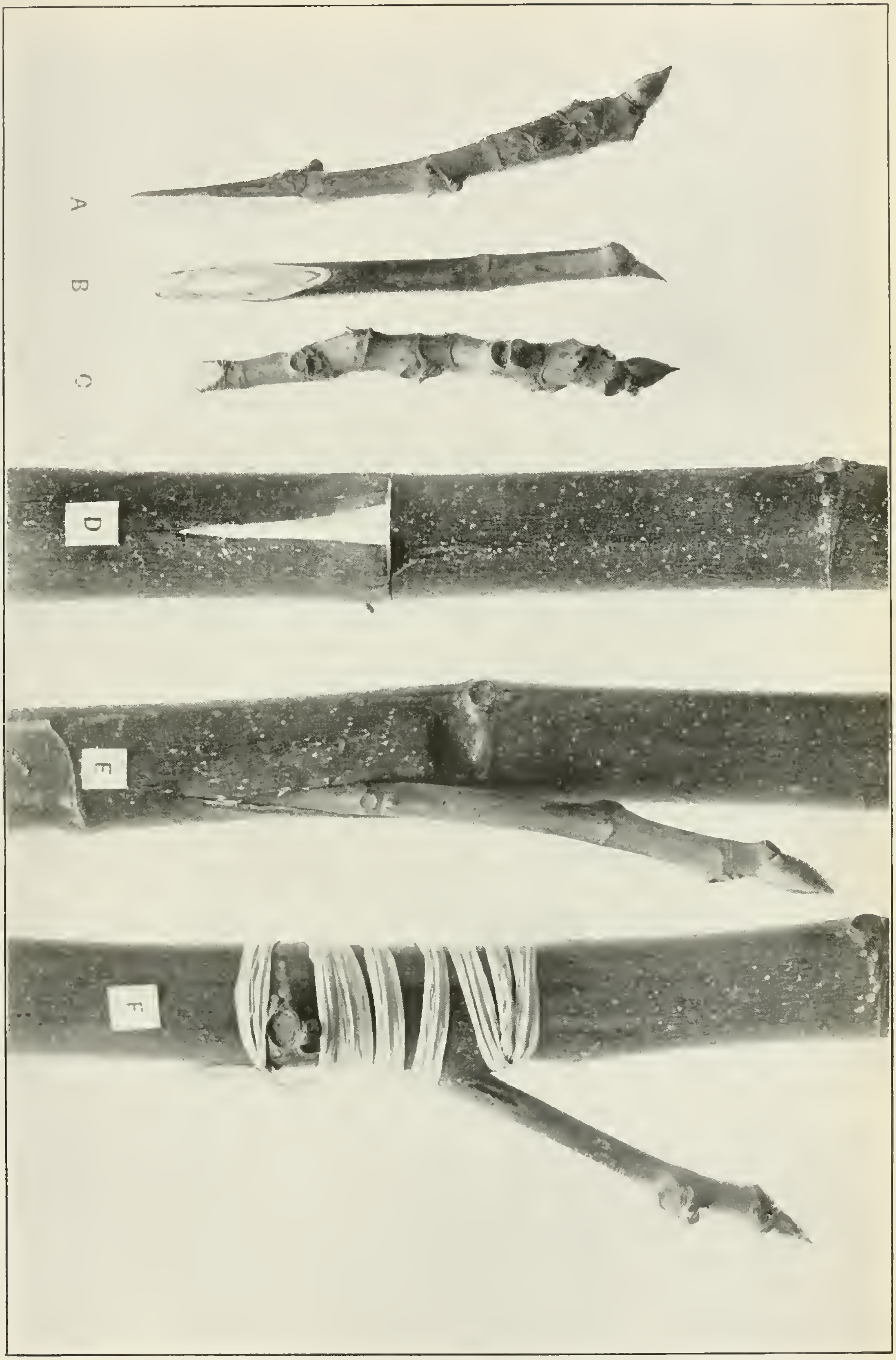
GERMINATION OF MANGO, SHOWING EIGHT PLANTLETS SPRINGING FROM ONE SEED.

FIG. 1.—CROWN GRAFTING THE LOQUAT, SHOWING A BAD UNION.

FIG. 2.—A 3-YEAR-OLD LOQUAT STOCK, BUDDED TWO YEARS.

FIG. 3.—SIDE GRAFTING THE LOQUAT ON 6-MONTHS-OLD SEEDLINGS.

A, Scion inserted; B, scion inserted, tied, and waxed; C, scion united and growing and stock cut back.



SCION BUDDING THE FIG.

VENEER GRAFTING THE TEA PLANT.

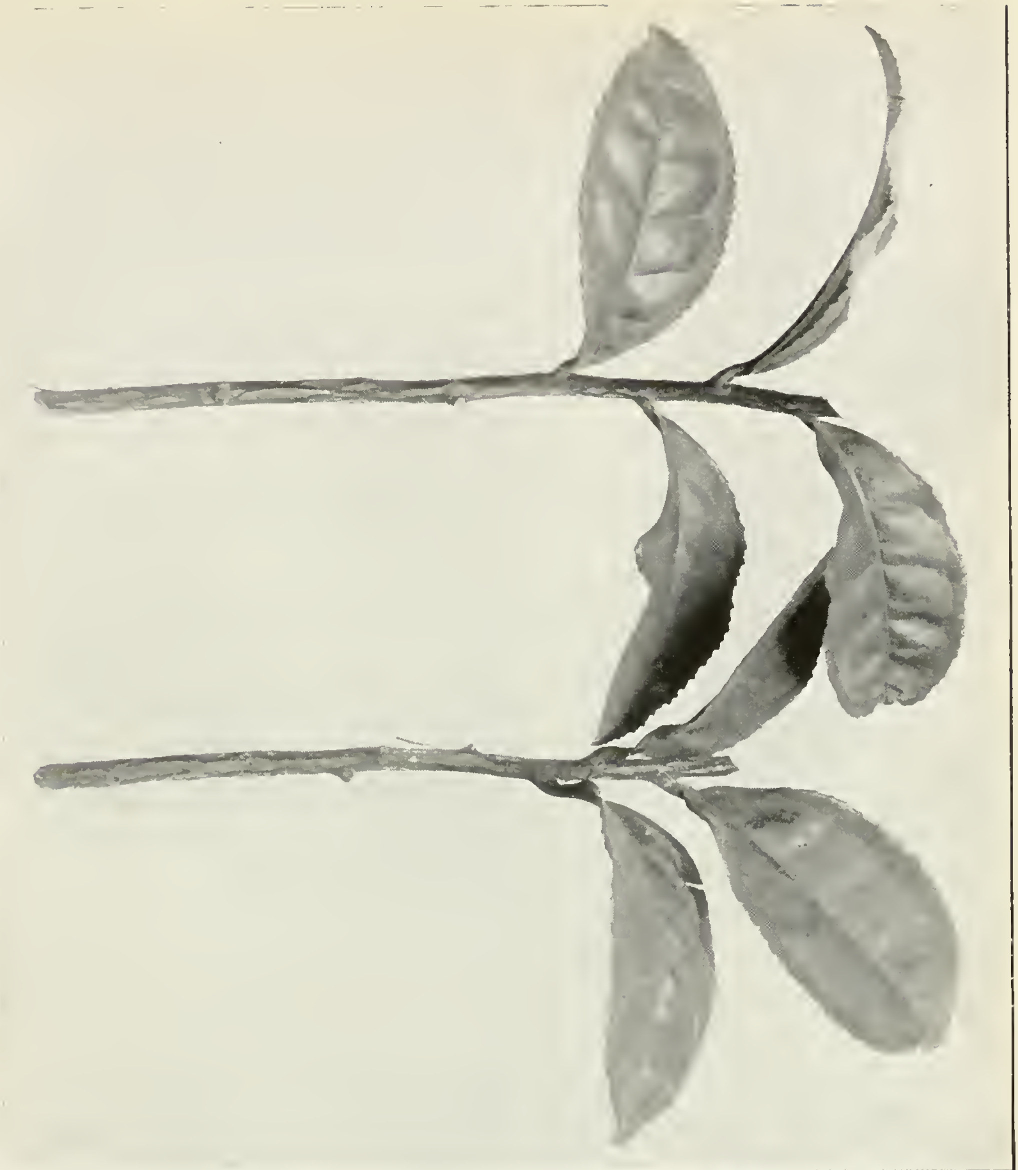


FIG. 1.—TEA CUTTINGS READY TO BE PLACED IN SAND.

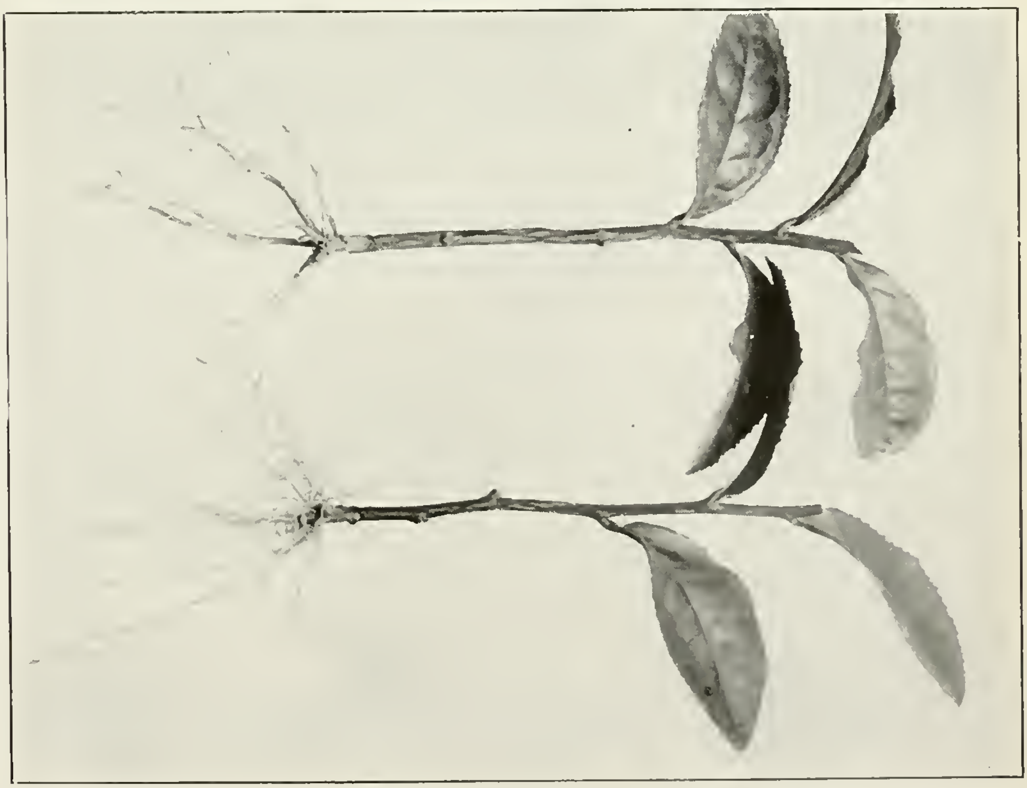


FIG. 2.—TEA CUTTINGS READY TO BE PLACED IN SOIL.

THE PROPAGATION OF TEA BY CUTTINGS.

MANILA HEMP. SIX-WEEKS-OLD SEEDLINGS. (NATURAL SIZE.)

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN No. 47.

B. T. GALLOWAY, *Chief of Bureau.*

THE DESCRIPTION OF WHEAT VARIETIES.

BY

CARL S. SCOFIELD,
BOTANIST IN CHARGE OF GRAIN GRADE INVESTIGATIONS.

BOTANICAL INVESTIGATIONS AND EXPERIMENTS.

ISSUED AUGUST 18, 1903.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1903.

BULLETINS OF THE BUREAU OF PLANT INDUSTRY.

The Bureau of Plant Industry, which was organized July 1, 1901, includes Vegetable Pathological and Physiological Investigations, Botanical Investigations and Experiments, Grass and Forage Plant Investigations, Pomological Investigations, and Experimental Gardens and Grounds, all of which were formerly separate Divisions, and also Seed and Plant Introduction and Distribution, the Arlington Experimental Farm, Tea Culture Investigations, and Domestic Sugar Investigations.

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[Continued on p. 3 of cover.]

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[Continued on p. 3 of cover.]

Triticum ......, or number ....

Size of plat ...., 190..

Variety description.

Wheat.

YOUNG STOOL.

Spreading.
Partly spreading.
Erect.

Color.

Yellow green.
Light green.
Medium green.
Dark green.
Gray green.
Purplish.

HALF-GROWN PLANT

Color.

Light green.
Medium green.
Dark green.
Light yellowish gree
Medium yellowish g
Dark yellowish gree
Light gray green.
Medium gray green.
Dark gray green.

Leaf blade.

Average length, cm.

Average width, cm.
Erect.
Ascending.
Drooping.
Smooth.
Scabrous.
Downy.
Glaucous.
Not glaucous.

Veins.

Prominent.
Not prominent.

End of blade.

Tapering.
Sides parallel

Sheath.

Green.
Green, shading to pu

Ligule.

Long.
Medium.
Short.
White.
Purple.

Auricles.

White.
Green.
White, with purple ti
Purple.
Hairy.
Partly hairy.
Smooth.

MATURE PLANT.

Height, cm. ....

Pear-shaped.
Thin.
Medium.
Plump.
Flat-cheeked.
Plump-cheeked.
Angular-cheeked.
Pointed at tip.
Pointed at base.
Blunt at tip.
Blunt at base.

Color.

Whitish.
Yellowish.
Clear amber.
Dull amber.
Clear red.
Dull red.

Brush.

Large.
Small.
Long.
Short.

Crease.

Deep.
Medium.
Shallow.
Wide.
Medium.
Narrow.

Cross section.

Very horny.
Horny.
Dull.
Starchy.

MILLING QUALITIES.

First class.
Good.
Medium.
Poor.

GENERAL CHARACTERISTICS.

Hardy.
Medium.
Delicate.
Early.
Medium.
Late.
Days maturing, ...
Autumn planted.
Spring planted.

Drought resistance.

Good.
Medium.
Poor.

Yield.

Per plant, ...

Per acre. ......

U. S. DEPARTMENT OF AGRICULTURE.

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BOTANICAL INVESTIGATIONS AND EXPERIMENTS.

SCIENTIFIC STAFF.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., June 15, 1903.

Sir: I have the honor to transmit herewith, and to recommend for publication as Bulletin No. 47 of the series of this Bureau, the accompanying paper entitled "The Description of Wheat Varieties." This paper was prepared by Mr. Carl S. Scofield, of this Bureau, and has been submitted by the Botanist with a view to publication.

The seven half-tone plates are essential for the purposes of this bulletin.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

With the exception of Indian corn, wheat is the most important cereal crop of the United States, and it therefore has been and will continue to be the object of much experimentation. Being a close-fertilized plant and consequently unable to cross pollinate in nature, wheat naturally maintains stronger hereditary lines than do open-fertilized crops under similar conditions, and therefore the variations that do occur more commonly retain their identity. In other words, wheat under cultural conditions tends to break up into varieties. Unlike many of our horticultural and garden crops, wheat has not up to this time been given the careful comparative study that its importance merits, and consequently the greatest confusion exists in the nomenclature of its varieties. For this reason important conclusions reached in one locality by costly experiments may be wholly misapplied in another locality.

It is important to have, as a basis for careful and intelligible experimentation with wheat, a correct understanding of variety names, and the important varieties of our American wheats should be carefully described and illustrated. Ordinarily in comparing the varieties of an agricultural plant it is the practice to gather a large series of samples of seed and grow the varieties side by side, making descriptions from the plants thus grown. By such a plan many of the varieties, being subjected to climatic and soil conditions to which they are not adapted, fail to develop their special and proper characteristics, and numerous complications arise. In undertaking the task of recording the characters of wheats, it is deemed advisable first to secure accurate descriptions of the varieties as they are found in the regions to which they are best adapted.

It is believed that the method of description herewith set forth will interest wheat experimenters in this important phase of their work, and lead to the adoption of some arrangement whereby wheat variety names may have a distinctly more definite meaning than at present.

FREDERICK V. COVILLE,
Botanist.

OFFICE OF BOTANICAL INVESTIGATIONS AND EXPERIMENTS,
Washington, D. C., May 20, 1903.

CONTENTS.

ILLUSTRATIONS.

THE DESCRIPTION OF WHEAT VARIETIES.

INTRODUCTION.

The nomenclature of the varieties of wheat now growing in the United States is somewhat tangled. The wheat plant is particularly unstable in type and a change of environment is likely to cause variations and result in plants better fitted to the new conditions. These plants, by producing more seed or seed of better quality, are the more vigorous progenitors, and gradually a complete change of type results. Other causes, such as errors in labeling seed packages for distribution, or the mixture of varieties by machines used in harvesting and thrashing, or by slight mixtures from the sacks and bins in which grain is stored, have all aided in bringing about an unfortunate confusion in the names of our standard varieties of wheat.

The origination of new varieties has also added its share to this confusion. These new varieties may have resulted from accidental or intentional hybridization, or merely by selection on the part of some enthusiast of seed from some plant that has attracted attention. The new variety may resemble one already existing so closely as to be indistinguishable, or it may be an entirely new form. In either case it is probably given a name without being anywhere even vaguely described or registered. The law of the survival of the fittest applies to wheat varieties as to other plants, and the poorer varieties in time give place to better sorts; but unfortunately the name frequently survives and immediately attaches to some other form.

In all literature regarding variety tests for comparative yield, adaptability, or hardiness, in fact in all discussions regarding wheat varieties, it is necessary to designate each by a name. In order to avoid hopeless confusion in so doing, it is essential that some system be used whereby these names may have a definite meaning; that is, that each name be connected with some one particular variety or type of wheat. This has been found absolutely necessary with all natural plants and with most of our cultivated horticultural and garden crops.

In connection with some work on American wheat varieties undertaken for the United States Department of Agriculture, a large number of varieties of wheat were collected from State experiment stations and some other sources with a view to describing and illustrating the standard sorts. It was found, however, that such an undertaking would be nearly impossible, for the present. Among the wheats so collected, cases were found where samples indistinguishable as to botanical characters were known by several different names, while on the other hand there were cases where one name was found serving for several samples strikingly different in appearance. (See Pls. I and II.)

A search through the available literature dealing with wheat varieties, chiefly experiment station bulletins and seed catalogues, giving accounts of new varieties and variety tests, showed that in most cases the wheats were either not described at all or had descriptions so meager and indefinite as to be useless.

The description of a wheat plant is, in itself, not a difficult undertaking, but it requires the consideration of a number of details which are sometimes hard to keep in mind or to find the right adjectives to fit. In order to reduce this work to the simplest terms, a form for variety descriptions has been prepared, a copy of which is inserted at the beginning of this bulletin. On this form are listed, in regular order, such adjectives as are deemed of the most importance in describing a variety of wheat. These adjectives are sufficiently numerous to express practically all ordinary conditions met in describing a variety. In order to make the description one needs only to glance at the form, note the alternatives mentioned regarding a certain characteristic, then to glance at the sample in hand to see which of the adjectives most nearly applies: this one is then checked, and the next set of adjectives taken up. This method greatly facilitates the work of describing varieties by suggesting the adjectives and by saving the trouble of writing out the words used. It also gives a basis for uniform description in all cases, which is a matter of prime importance.

The form is printed on strong, thin paper, which may be filed in any manner desired and preserved for future reference. All the data regarding any plant or variety for a given year are thus brought together on a single sheet of paper.

It is believed that this system offers the means of straightening out the nomenclature of our wheat varieties, of preventing errors in distributing wheat samples for testing purposes, of studying the effect of changes of environment on wheat varieties, and of noting the variations resulting from hybridization. New varieties that may be originated may be, by this method, accurately described, and if it is found desirable these new varieties, so described, may be registered by some recognized and competent organization.

Further than this, published results of variety tests, when supplemented by more accurate descriptions, will be infinitely more valuable to the reader than they are at present.

The idea of describing wheats by a printed form was suggested by Dr. N. A. Cobb, government botanist of New South Wales.

EXPLANATION OF FORM.

The heading of the form has spaces for writing in the variety name or number, the place where grown, and the year grown. There is also space for giving size of plat or field grown, or, in case very small plats or single plants are the basis of the description, the number of plants should be stated. After the word *Triticum* the species, whether *æstivum* (*vulgare*) or *durum*, should be written. This form is made up to describe varieties of these two species only. Varieties of the other species of *Triticum* are not extensively enough known or cultivated in this country to warrant the expansion of this form to include their description.

The adjectives used on this form are grouped under the following heads: 1, Young stool; 2, Half-grown plant; 3, Mature plant; 4, Head (field notes); 5, Head (laboratory notes); 6, Awns; 7, Spikelet; 8, Grain; 9, Milling qualities; 10, General characteristics.

Young stool.—The terms *spreading*, *partly spreading*, and *erect* apply to the general form of growth of the young plant before the appearance of the stem. In case of wheats planted in the autumn, these observations should be made in the late autumn or very early spring.

The shades of color are comparative and difficult to describe accurately and can be noted to the best advantage only when plats of grain may be compared side by side.

Half-grown plant.—By this is meant the stage of growth when the head is just appearing from the sheath of the upper leaf; in other words, just before flowering time. The shades of color are here again difficult to describe and can be noted with any degree of accuracy only when comparison between plats of grain is possible.

The measurements of the leaf blade should be taken on the upper leaf of each of at least ten average plants, when that many are available, the maximum measurement of each dimension of the leaf being the one used in averaging. The terms *erect*, *ascending*, and *drooping* apply to the upper leaf after the head is well out of the sheath, and the terms *smooth*, *scabrous*, and *downy* apply to the surfaces of the leaf blade and to the leaf sheath. The term *glaucous* is defined as "covered with a bluish-white bloom" and refers to the surface of the young leaves.

The terms *prominent* and *not prominent* applied to the veins of the leaf are difficult of accurate definition and should be considered only when comparison of varieties is possible.

The terms *tapering* and *sides parallel* applied to the end of the leaf blade deal with the general shape of the distal one-third of the upper leaf.

The sheath is that portion of the leaf which clasps the stem, and the color terms here used are self-explanatory.

The ligule (Pl. III, fig. 1) is the thin, transparent tissue borne at the juncture of the blade and sheath of the leaf and clasping the stem above the leaf. The terms *long*, *medium*, and *short* apply to the height this tissue reaches up the stem. A ligule 2.5 mm. or longer is considered long, while one 2 mm., more or less, is medium, and it is short when less than about 1.7 mm.

The leaf auricles (Pl. III, fig. 1, No. 2) are the thin projections of tissue which are the outgrowths from the base of the leaf blade or from the thickened tissue at the juncture of the blade and sheath of the leaf. The terms applying to these need no explanation.

Mature plant.—The height measurement is marked to be stated in centimeters and, whenever possible, should be made when the plant is still standing in the field in its natural position. The terms *strong*, *medium*, and *weak* apply to the general vigor of the plant, including its ability to stand erect and its branching or "stooling." The *diameter below the head* should be measured at the point where the straw is smallest, between the upper leaf and the base of the spike. When this measurement is made some sort of calipers must be used. The terms *furrowed*, *medium*, and *smooth* apply to the surface of the straw, and these terms should be used only where straws may be compared side by side, as all wheat straws are more or less furrowed.

The terms *solid*, *semisolid*, and *hollow* (Pl. V, figs. 1, 2, and 3) apply to the amount of pith in the culm about halfway between the top of the upper leaf sheath and the base of the head, solid being used when the straw is entirely full of the pith, semisolid when only a very small hole through the center of the straw is open, and hollow when the pith is entirely absent or consists only of a thin layer on the inside of the culm.

The terms *thick*, *medium*, and *thin* applied to the walls of the culm are relative, and can be stated only after comparing different plants. In considering the thickness of the walls, the layer of pithy tissue on the inside must not be included as part of the wall. The thickness of the wall indicates to some extent the rigidity of the culm and the ability of the plant to stand erect.

The color terms here are applied to the culm after the plant is completely matured and are, as before, only comparative.

The terms *scanty*, *medium*, and *abundant*, applying to the foliage, should be marked only when opportunity is had of seeing various plats of grain together under similar conditions.

The percentage of rust for leaves and stems must be estimated, considering 100 per cent damage in either case as applying to cases where the surface of the leaves or stem is completely covered with rust pustules, and zero per cent when no rust is observed. This estimate may be based on a single plant or on a whole plat of grain, as occasion requires.

When estimating smut of either sort the same is true. When every grain in the head or in every head is infected the percentage is 100, and zero when the plant or plat is entirely free from smut.

Head (*field notes*).—The term *beardless* is applied to those heads the flowering glumes of which bear no awns longer than 1 centimeter; *partly bearded* where some of the flowering glumes bear awns longer than 1 centimeter while others bear awns much shorter, and *bearded* when all the flowering glumes bear awns longer than a centimeter. The terms *erect*, *leaning*, and *nodding* apply to the way the head is borne by the stem at or after maturity. The dates of appearance, flowering, and maturing need no explanation.

The terms *shattering badly*, *medium*, and *none* apply to the ability of the glumes to hold the grain after maturity. These are only comparative terms, as this is a quality difficult of actual measurement, but it is an item of great importance in all the large wheat-producing regions and should be most carefully considered.

Head (*laboratory notes*).—The length measurement should be taken from the lowest joint of the head to the tip of the apical flowering glume, not counting the awn if one is borne by this glume. The terms *very open* (Pl. III, fig. 2, No. 1), *open*, *medium*, *compact*, and *crowded* (Pl. III, fig. 2, No. 2) apply to the way the spikelets are borne in the head. These are relative terms, since the size of the spikelet has some influence in this matter, making the statement of this quality by giving the distance between the joints unsatisfactory.

Under shape of spike, the term *tapering toward apex* should be applied to those which taper gradually from about the middle or below. *Tapering both ways* should be applied to those spikes which are spindle-shaped or larger in diameter at the middle than at either end. *Uniform* (Pl. III, fig. 2, No. 1) applies to those spikes which are very nearly the same diameter throughout their length. *Clubbed* (Pl. III, fig. 2, No. 2) should be applied to those spikes which are larger at the tip than below. The term *tip acute* (Pl. III, fig. 2, No. 1) is applied to those spikes which terminate with one or two undeveloped spikelets, and *tip blunt* (Pl. III, fig. 2, No. 2) to those having terminal spikelets well filled out; *base abrupt* to those having basal spikelets well developed, and *base tapering* to those having the basal spikelets very small or undeveloped. *Square* applies to those spikes the diameters of which through and across the spikelets are about the same, and *flattened with spikelets* (Pl. III, fig. 2, Nos. 5 and 6) to those spikes which have the diameter through the spikelets smaller than the diameter across the individual spikelet, the condition commonly found in *Triticum æstivum;* while *flattened across spikelets* (Pl. III, fig. 2, Nos. 3 and 4) applies to those spikes having the diameter through the spikelets greater than that across them, the condition common to the varieties of *Triticum durum*. The terms *straight* and *slightly curved* need no explanation.

The color terms are again relative.

Awns.—The terms *long*, *medium*, and *short* are only comparative, as are the terms *slender*, *medium*, and *stout*. The terms *orderly*, *medium*, and *irregular*, and *parallel*, *spreading*, and *spreading widely* apply to the way the awns stand in relation to the head. *Orderly* is used when the awns are uniform in length or position, and *irregular* when some of them are long and others short or when some are parallel to the spike and others twisted or divergent. *Deciduous*, *partly deciduous*, and *persistent* apply to the way the awns are retained after the plant reaches maturity. Some plants normally have awns so brittle that they break at the point of juncture with the flowering glume soon after the plant reaches maturity.

The color terms again are relative.

Spikelets.—The terms *spreading widely*, *spreading*, and *narrow* apply to the width of the spikelet, or the way the glumes are set. Plate IV shows extreme cases of the width of spikelets. The *number of grains per spikelet* means the number of grains borne in an average well-developed spikelet.

The structure of the spikelet and the shape of the various glumes are of such importance in describing wheat varieties that they deserve special attention. The spikelet is composed of several flowers borne alternately on a short branch of the spike called the rachilla, and subtended by two large bracts, or outer, empty glumes. These glumes are hereafter called the outer glumes and should not be confused with the flowering glume which surrounds each flower or grain. The long awns of the spike, when present, are borne on the flowering glumes. The outer glumes never bear awns longer than two or three centimeters.

In Plate V, fig. 13, is shown a spikelet split apart to show the rachilla and the way the glumes are borne, and in the same plate (fig. 19) is shown the compound spikelet found in the so-called Mummy wheat, or Seven-headed wheat. In the latter case the spike is branched and each branch, in turn, bears true spikelets.

There is usually borne on the rachis at the base of each spikelet, below the outer glumes, a growth of short, bristly hairs (Pl. IV, fig. 1) which are here called basal hairs and which may be described by the terms *long*, *medium*, *short*, and *wanting*, and in color either *white* or *brown*. These hairs should not be confused with the hairs sometimes present on the outer glumes.

The outer glume may be either hairy, partly hairy, or smooth. Plate VII, figs. 4 and 6, shows types of hairy and smooth glumes, while in Plate V, fig. 14, is shown a spikelet of which not only the outer glumes are hairy but also the flowering glumes as well. The terms *glossy*, *medium*, and *dull* apply to the surface of the outer glume, as do the terms *uniform in color* and *streaked*.

The terms *broad*, *medium*, and *narrow* apply to the shape of the outer glume; that is, to the way the wings on either side of the keel fit around the flowering glume. Plate IV, fig. 2, shows a spikelet with narrow outer glume, while in Plate V, fig. 19, the glumes on the compound spikelet are relatively broad. The terms *long*, *medium*, and *short* apply to the relative length of this outer or flowerless glume. The spikelet in Plate IV, fig. 2, has short outer glumes, while the spikelet in fig. 1 has long glumes; that is, glumes nearly or quite as long as the flowering glumes.

The terms *firm*, *medium*, and *weak* under *attachment* have to do with the firmness of the attachment of the glumes, when ripe, to the rachilla upon which they are borne. This firmness of attachment indicates the ability of the glumes to retain the grain after the plant reaches maturity.

The keel of the outer glume is the pronounced central nerve and may be broad, medium, or narrow. Varieties of *Triticum durum* are characterized by the broad keel (Pl. VII, fig. 1) which is prominent throughout its entire length. The keel is always present, but may not be distinct in some varieties of *Triticum æstivum.*

The beak of the outer glume is the tip of the keel. It may be either long (Pl. VI, figs. 6 and 7), medium (fig. 5), or short (figs. 1 and 2), and acute or blunt.

The shoulder of the outer glume is that portion on either side of the midrib at the tip of the glume and it may be either broad (Pl. VI, fig. 2), medium (fig. 1), or narrow (fig. 5), and square (Pl. VII, fig. 5), sloping (fig. 1), or round (fig. 6).

The auricle of the outer glume (Pl. VII, fig. 5) occurs, when present, at the tip of the shoulder, which is sometimes extended into a distinct ear. It may be sharp (Pl. VI, fig. 4), medium, blunt (fig. 1), or wanting (fig. 3).

The auricle notch (Pl. VII, fig. 5) is the notch in the tip of the outer glume between the auricle and the beak. It may be deep (Pl. VI, fig. 1), medium, shallow (fig. 7), or wanting (fig. 5).

The apical glumes are the outer glumes of the apical spikelet, and they sometimes show distinct differences. Two types of these outer glumes, of which there are but two on each spike, are shown in Plate VII, figs. 2 and 3. These glumes may be keeled or not keeled, notched or rounded, and they may be similar or dissimilar.

Grain.—The terms *very hard*, *hard*, *medium*, *soft*, and *very soft* are only comparative, but are convenient in distinguishing between different sorts of grain.

The size is determined by weighing 100 average seeds. This determination should be made in duplicate, at least.

The terms *long*, *medium*, and *short*, applying to the shape of the grain, are only comparative. They apply to the relative length and diameter of the grain. Extreme types are shown in Plate V. The grain may also be either curved (fig. 4), straight (fig. 6), or pear shaped (fig. 8). The pear-shaped grain is the kind sometimes known as club wheat.

The term *clubbed* has been applied indiscriminately to either the shape of the head or the shape of the grain, but in the accompanying form the word *clubbed* is reserved to describe the shape of the head, while the term *pear-shaped* is used for the grain. The grain may be thin, medium, or plump, and flat-cheeked, plump-cheeked (Pl. V, fig. 12), or angular-cheeked (fig. 10), the cheek of the grain here meaning the portion on either side of the crease. It may also be pointed or blunt at the tip and pointed or blunt at the base.

The color terms are again only comparative.

The brush of the grain is the growth of hair at the tip or the end opposite the germ. The terms *large* and *small* apply to the area over which the brush is borne, and the terms *long* and *short* apply to the length of the hairs. The grain of *Triticum durum* is characterized by the extreme shortness of the brush (Pl. V, fig. 4), but some slight growth of hair is always present, even in varieties of this species.

The crease of the grain is the indentation extending along the side opposite the germ. This crease may be deep, medium, or shallow; that is, the portion of the endosperm between the bottom of the crease and the outer skin of the berry may be thick or thin and the crease may be either wide, medium, or narrow. The cross sections of the grain shown in Plate V, figs. 10, 11, and 12, give a good example of extreme cases of this characteristic. The terms *very horny*, *horny*, *dull*, and *starchy* apply to the texture of the grain in cross section.

Milling qualities..—The terms *first-class*, *good*, *medium*, and *poor* are purposely indefinite here because it is impossible to give in so brief a space more definite expression of the characters which go to determine the milling qualities of the wheat and the terms used give at least an idea of the opinion of the observer.

General characteristics.—The terms *hardy*, *medium*, and *delicate*, *early*, *medium*, and *late* need no explanation. The *days maturing* should be given as the time from the planting of the grain until the plant is fully matured. *Autumn planted* and *spring planted* refer to the season of the year when the grain was sown. *Drought resistance* is a term applied to the ability of wheats to mature well under droughty conditions; the adjectives *good*, *medium*, and *poor* serve to indicate the observer's idea of the relative merits of a variety in this regard. The amount of yield should be stated in grams per plant or bushels per acre.

PLATES.

DESCRIPTION OF PLATES.

PLATE I. Two examples of different types of wheat having the same name. Natural size. Fig. 1.—The type of a variety known as Early Ripe, from the Ohio State Experiment Station. Fig. 2.—The type of the variety Early Ripe, from the Oklahoma Experiment Station. Fig. 3.—The type of a variety known as Emporium, from the Washington State Experiment Station. Fig. 4.—The type of the variety Emporium, from the Utah Experiment Station.

PLATE II. Three different types of wheat having the same name. Natural size. Fig. 1.—A beardless, smooth-chaffed wheat, known as Velvet Chaff, from the Utah State Experiment Station. Fig. 2.—A beardless, hairy-chaffed wheat, known as Velvet Chaff, from the Colorado State Experiment Station. Fig. 3.—A bearded, hairy-chaffed wheat, known as Velvet Chaff, from the Ohio State Experiment Station.

PLATE III. Fig. 1.—Auricles and stipules of wheat leaves. Enlarged seven times. Showing point of juncture of blade and sheath of the leaf. No. 1.—The stem removed to show the entire ligule. No. 2.—The leaf in natural position, with the sheath clasping the stem. Fig. 2.—Types of wheat spikes. Natural size. No. 1.—Spike beardless, nine centimeters long, very open, uniform, tip acute, base tapering, flattened with the spikelets, and straight; glumes smooth. No. 2.—Spike bearded, eight centimeters long, crowded, clubbed, tip blunt, base tapering, square and straight; glumes hairy. Nos. 3 and 4.—Spike of *T. durum* shown in two positions to illustrate "flattened across spikelets." The diameter of the spike *through* the spikelets (No. 3) is *greater* than *across* the spikelets (No. 4.) Nos. 5 and 6.—Spike of *T. æstivum* shown in two positions to illustrate "flattened with spikelets." The diameter of the spike *through* the spikelets (No. 5) is *less* than *across* the spikelets (No. 6.)

PLATE IV. Different types of wheat spikelets. Enlarged five times. Fig. 1.—A narrow spikelet containing three grains with long basal hairs, and with long, smooth, narrow outer glumes, each with a narrow keel and a long, acute beak; the flowering glumes firmly attached, and with the awns of two of them broken off. Fig. 2.—A broad spikelet containing five grains with short basal hairs, and with short, smooth, narrow outer glumes, each with a narrow keel and a very short, blunt beak. The flowering glumes are firmly attached, and, while each has an awn, these are so short that the spike would be called beardless.

PLATE V. Various types of culms, grain, and spikelets. Twice natural size. Fig. 1.—Culm solid. Fig. 2.—Culm semisolid. Fig. 3.—Culm hollow. Fig. 4.—Grain long, curved; brush short. Fig. 5.—Grain short, tip blunt, base pointed; brush large, long. Fig. 6.—Grain medium length, straight; tip blunt, base pointed; brush short. Fig. 7.—Grain short; tip and base pointed; brush small, long. Fig. 8.—Grain short, pear-shaped; tip pointed, base blunt; brush small, long. Fig. 9.—Grain short, straight; base and tip blunt; brush large, long. Fig. 10.—Section of grain showing angular cheek, with crease deep and narrow. Fig. 11.—Section of grain showing plump cheek, with crease deep and broad.

TWO EXAMPLES OF DIFFERENT TYPES OF WHEAT HAVING THE SAME NAME.
NATURAL SIZE.

THREE DIFFERENT TYPES OF WHEAT HAVING THE SAME NAME.
NATURAL SIZE.

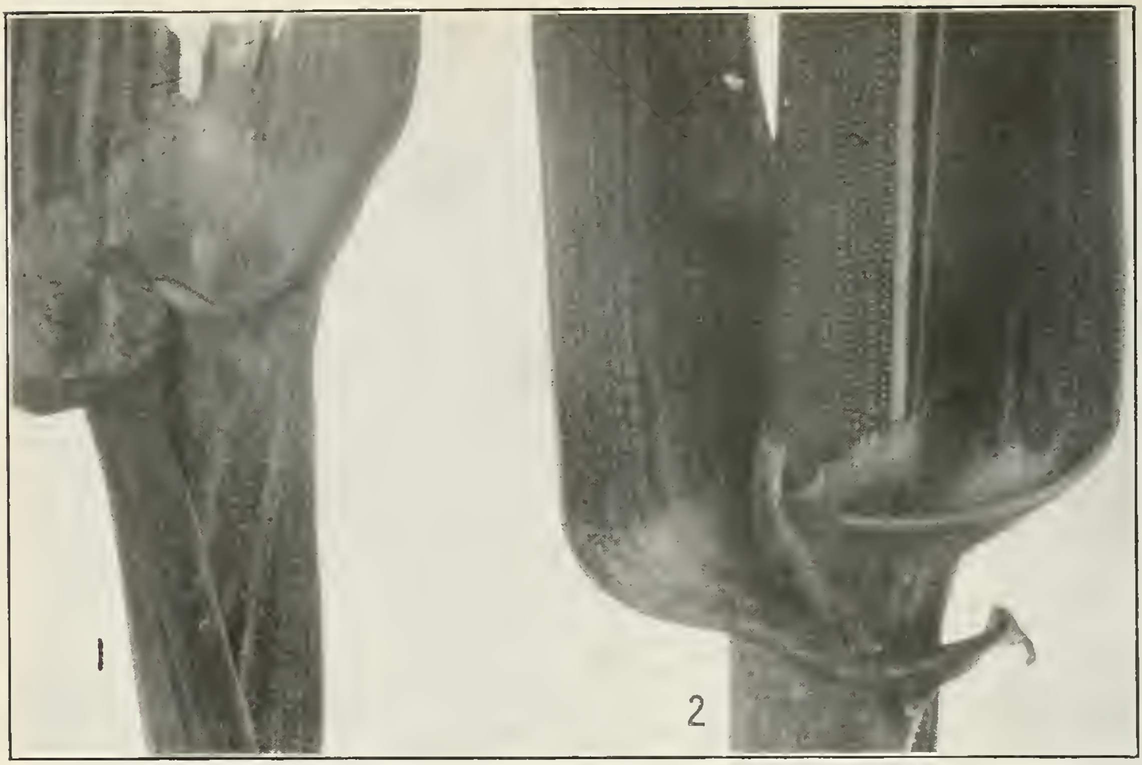
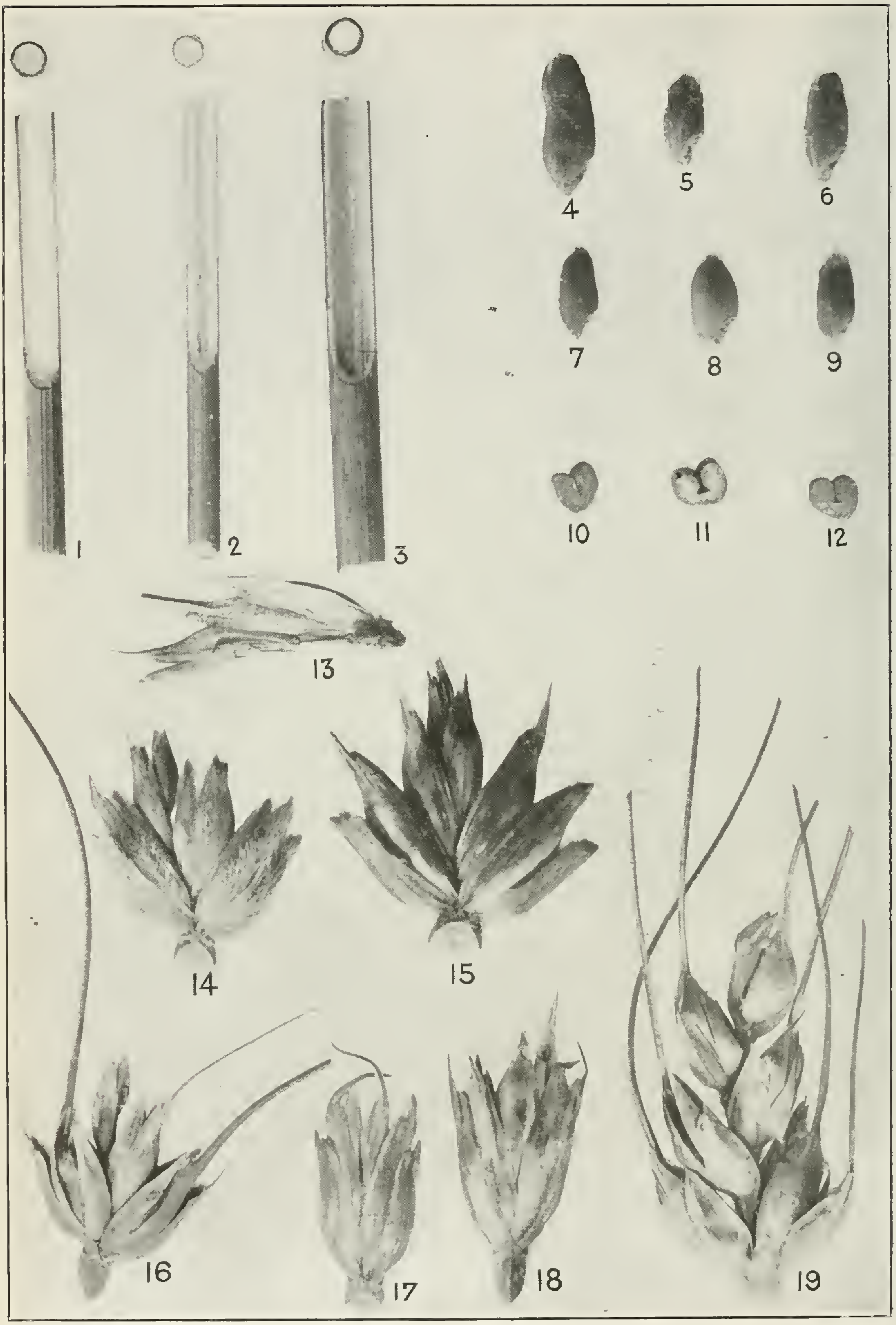


FIG. 1.—AURICLES AND LIGULES OF WHEAT LEAVES. ENLARGED SEVEN TIMES.

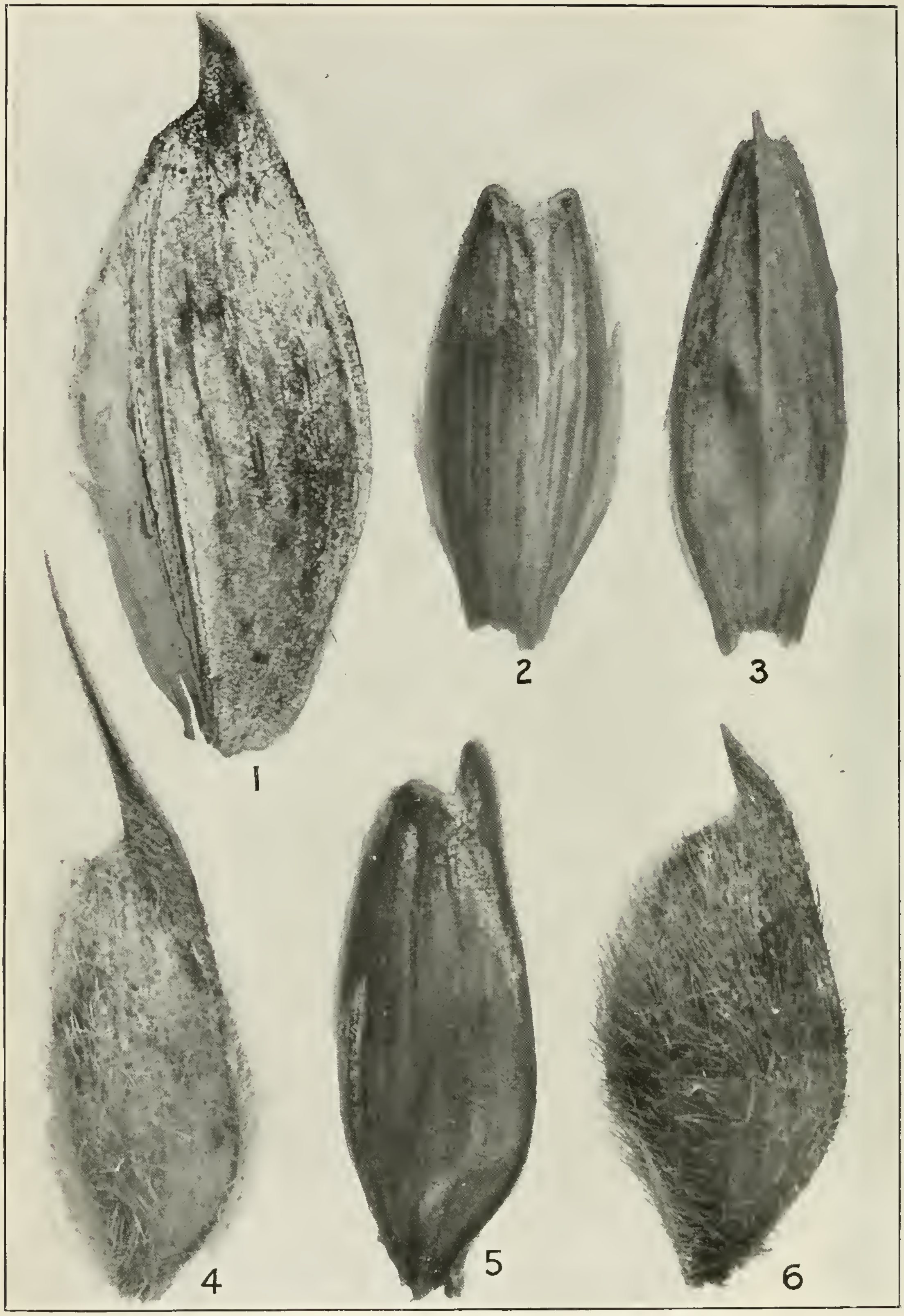
FIG. 2.—TYPES OF WHEAT SPIKES. NATURAL SIZE.

DIFFERENT TYPES OF WHEAT SPIKELETS. ENLARGED FIVE TIMES.



VARIOUS TYPES OF CULMS, GRAIN, AND SPIKELETS. TWICE NATURAL SIZE.

OUTER GLUMES FROM VARIOUS TYPES OF WHEAT SPIKELETS. ENLARGED SEVEN TIMES.



OUTER GLUMES FROM VARIOUS TYPES OF WHEAT SPIKELETS. ENLARGED SEVEN TIMES.

Fig. 12.—Section of grain showing plump cheek, with crease medium deep and narrow. Fig. 13.—Portion of spikelet showing rachilla and arrangement of glumes. Fig. 14.—Simple spikelet, beardless, spreading; glumes hairy, medium length; beak short and blunt. Fig. 15.—Simple spikelet, beardless, spreading widely; glumes smooth, short; beak short and blunt. Fig. 16.—Simple spikelet, bearded, spreading; glumes smooth, short, attachment weak; beak long and acute. Fig. 17.—Simple spikelet, beardless, narrow; glumes smooth, medium length; beak medium and blunt. Fig. 18.—Simple spikelet, beards broken off, narrow; glumes smooth and long; beak long and acute. Fig. 19.—Compound spikelet from "seven-headed" wheat; bearded; glumes smooth, medium length, broad; beak short and acute.

Plate VI. Outer glumes from various types of wheat spikelets. Enlarged seven times. Fig. 1.—Glume smooth, medium size; keel narrow; beak short and blunt; shoulder medium and square; auricle medium, notch deep. Fig. 2.—Glume smooth, broad, medium length; keel narrow; beak short and blunt; shoulder broad and sloping; auricle wanting. Fig. 3.—Glume similar to fig. 2, but from the other side of spikelet. Fig 4.—Glume smooth, broad, and short; keel narrow; beak short and acute; shoulder medium and round; auricle sharp; notch medium. Fig. 5.—Glume smooth, medium size; keel narrow; beak medium and acute; shoulder narrow and sloping; auricle wanting. Fig. 6.—Glume smooth, long, and broad; keel narrow; beak long and acute; shoulder narrow and sloping; auricle wanting. Fig. 7.—Glume smooth, medium size; keel narrow; beak long and acute; shoulder medium and round; auricle sharp; notch shallow.

Plate VII. Outer glumes from various types of wheat spikelets. Enlarged seven times. Fig. 1.—Glume smooth, broad, and long; keel broad; beak short and acute; shoulder medium and sloping; auricle wanting. Fig. 2.—Outer glume from an apical spikelet, notched and without a keel. Fig. 3.—Outer glume from an apical spikelet, notched and keeled. Fig. 4.—Glume hairy, medium, and short; keel narrow; beak long and acute; shoulder medium and square; auricle wanting. Fig. 5.—Glume smooth, medium sized; keel narrow; beak short and blunt; shoulder medium and square; auricle medium; notch deep. Fig. 6.—Glume hairy, short, and broad; keel narrow; beak short and acute; shoulder broad and round; auricle wanting.

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U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 48.

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THE APPLE IN COLD STORAGE.

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POMOLOGICAL INVESTIGATIONS.

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BULLETINS OF THE BUREAU OF PLANT INDUSTRY.

The Bureau of Plant Industry, which was organized July 1, 1901, includes Vegetable Pathological and Physiological Investigations, Botanical Investigations and Experiments, Grass and Forage Plant Investigations, Pomological Investigations, and Experimental Gardens and Grounds, all of which were formerly separate Divisions, and also Seed and Plant Introduction and Distribution, the Arlington Experimental Farm, Tea Culture Investigations, and Domestic Sugar Investigations.

Beginning with the date of organization of the Bureau, the several series of bulletins of the various Divisions were discontinued, and all are now published as one series of the Bureau. A list of the Bulletins issued in the present series follows.

Attention is directed to the fact that "the serial, scientific, and technical publications of the United States Department of Agriculture are not for general distribution. All copies not required for official use are by law turned over to the Superintendent of Documents, who is empowered to sell them at cost." All applications for such publications should, therefore, be made to the Superintendent of Documents, Union Building, Washington, D. C.

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16. A Preliminary Study of the Germination of the Spores of Agaricus Campestris and Other Basidiomycetous Fungi. 1902. Price, 10 cents.
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21. List of American Varieties of Vegetables for the Years 1901 and 1902. 1903. Price, 35 cents.

[Continued on p. 3 of cover.]

SCALD ON YORK IMPERIAL APPLES.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 48

B. T. GALLOWAY, *Chief of Bureau*

THE APPLE IN COLD STORAGE.

BY

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AND

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POMOLOGICAL INVESTIGATIONS.

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BUREAU OF PLANT INDUSTRY.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., June 18, 1903.

Sir: I have the honor to transmit herewith a paper entitled "The Apple in Cold Storage," and respectfully recommend that it be published as Bulletin No. 48 of the series of this Bureau.

This paper was prepared by Mr. G. Harold Powell, Assistant Pomologist in Charge of Field Investigations, and Mr. S. H. Fulton, Assistant in Pomology, and has been submitted by the Pomologist with a view to publication.

The illustrations which accompany this report, consisting of five colortypes and one half-tone plate, are considered essential to a full understanding of the text.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

Apple culture has attained such proportions in the United States that the harvesting and disposition of the crop have become matters of national importance. A general failure of the crop of winter apples in any season results in serious disturbance of commercial conditions in many important agricultural regions and involves heavy losses to mercantile and transportation interests, as well as to the growers. At the same time it inflicts a serious hardship upon consumers by depriving them of this the most useful fruit in their household economy.

Next to crop failure and the control of injurious diseases and insects, the most important feature of commercial apple growing at the present time is undoubtedly the preservation of the crop for a sufficient time to permit its distribution to consumers in sound and wholesome condition, in both home and foreign markets, throughout the winter season. This feature has become very prominent since apple orcharding has developed on a large scale in the middle and more southern States, where the climatic conditions at the time of the apple harvest are frequently unfavorable to long durability of fruit. Under the deteriorating influence of warm weather during September and October a large part of the crop frequently reaches full ripeness and is thrown upon the market in perishable condition before midwinter. This results in disastrous gluts and ruinously low prices for a time, followed by scarcity of fruit and abnormally high prices to the consumer in the late winter and early spring.

The successful keeping of apples on a large scale in refrigerated storage, which began about 1890, was welcomed by growers and dealers as a solution of the problem, and the practice of storing in this way has since developed to very large proportions. Experience has demonstrated, however, that in many instances fruit stored in such houses in the fall has failed to come out in good condition in the late winter or spring, to the serious loss of the owner. It has long been observed also that different lots of fruit in the same storage room behave differently, some keeping in excellent condition, while others spoil. A browning of the skin of the apple while in storage or shortly after removal therefrom, generally known as "scald," also frequently lessens the beauty of the fruit and therefore its selling value, even when its food value is but little impaired.

In investigating this subject with a view to reducing the uncertainty and the loss, it has been found necessary to take up the entire question of orchard location and cultural treatment, as well as the methods employed in picking, packing, and shipping the fruit, all of these having important bearing on the durability of the product after it reaches the storage house. Systematic work along these lines was begun in the autumn of 1901 and has been continuous since that time. The problems involved are so complex and varied in view of the large number of varieties now commercially grown and the wide range of climatic and soil conditions involved that accurate and comprehensive generalization of results will require several repetitions of most of the experiments. Certain discoveries of distinct economic importance have been made during the progress of these investigations which appear to render the publication of this preliminary report advisable at this time in order that they may be available for application to the handling of the crop of the current season.

The investigation referred to has been conducted and this bulletin prepared by Mr. G. Harold Powell, Assistant Pomologist in Charge of Field Investigations, and Mr. S. H. Fulton, Assistant in Pomology, under the direction of Mr. William A. Taylor, Pomologist in Charge of Field Investigations. While the experimental work of the Department has covered but two seasons, the experience of many of the leading cold-storage men of the country has been drawn upon and freely given. It is therefore believed that the bulletin in its present form affords a safe guide in the matter of winter-apple storage in refrigerated warehouses.

G. B. Brackett,
Pomologist.

Office of Pomological Investigations,
Washington, D. C., May 29, 1903.

CONTENTS.

ILLUSTRATIONS.

THE APPLE IN COLD STORAGE.

INTRODUCTION.

The application of cold temperatures to the preservation of fruits has profoundly influenced the development of American fruit growing. When orchard products had to be transported to market in common freight cars and express cars or by boats running on slow schedules, and the surplus fruit was stored in cellars, pits, and fruit houses without artificial cooling, it was necessary to dispose of the crop quickly in local markets to prevent unusual losses from decay. Even under the most favorable conditions, the markets were often oversupplied in the fall months, with an accompanying demoralized condition in the fruit trade, especially when the weather was hot, while the supply of fruit was exhausted early in the winter and the markets were barren during the remaining season.

The development of the fruit-refrigerator-car service and other improved methods of transportation have made fruit growing possible in remote parts of the country and have facilitated the wide distribution of the most perishable products. Mechanical refrigeration on shipboard and the introduction of other special facilities for fruit transportation are extending the markets for fresh fruit abroad. The growth of the cold-storage warehousing business is making the season of fresh fruits and vegetables perennial. It is distributing them more uniformly throughout the season and is thereby contributing to their freer use, to more steady markets and uniform prices, and to a more stable fruit business.

INFLUENCE OF COLD STORAGE ON THE APPLE INDUSTRY.

Cold storage is having an important influence in developing the apple industry as a stable business. Instead of an incidental feature of the general farm, the apple is now the principal crop in large sections of the country, and its production and the handling and marketing of the crop are becoming highly specialized forms of agriculture and of trade.

Formerly the marketing of the crop was largely controlled by the apple grower, but now the growing of the crop and its sale are rapidly differentiating into two distinct lines. In many of the principal fruit-growing districts the handling of the crop and its marketing are controlled largely by fruit organizations or by apple merchants who buy the fruit in the orchards and who, through the special development of fruit and market statistics, are better able than the fruit grower to regulate its distribution and sale. This greater stability and specialization in apple growing is accompanied by a large amount of speculation. Through a combination of the buyers the fruit may not always sell in the orchard for its real value, but on the other hand the severe competition in buying in those sections where the industry is especially well developed frequently brings the grower the highest prices.

Apple storage is not always profitable. It is an insurance against the premature deterioration of the fruit, but when the picking season is unusually hot and there are delays in getting the fruit into storage, the subsequent losses are sometimes very heavy. On the other hand the autumn may be unusually cool and favorable for storing large quantities of apples in common storage. As a result the markets are well supplied with this fruit through the winter, causing the cold-storage stock to be held back till late in the season, when it has to be rushed on the market and sold at a sacrifice on account of the approaching warm weather and the free use of southern early fruits.

On the whole the development of the cold-storage business is proving beneficial to the apple industry in encouraging the development of apple growing over large territories, in making the investment of capital in it safer, in developing it as a highly specialized type of agriculture and trade, and in making a valuable food product available to an increasing number of people over a greater part of the year.

THE EXTENT OF THE COLD-STORAGE WAREHOUSING INDUSTRY.

The magnitude of the cold-storage warehousing business and its importance to the fruit industry are not generally recognized. Accurate statistics are difficult to obtain, but in 1901 it was estimated[a] that the capacity of the cold-storage warehouses, including meat, egg, and butter storage, was 150,000,000 cubic feet of space, of which 50,000,000 cubic feet, distributed in 600 houses, were devoted to fruit storage. Since 1901 there has been a large increase in the number of fruit-storage houses, especially in the apple-growing districts, where many plants, with a capacity of 5,000 to 30,000 barrels, have been erected in or near the orchards or at the railroad stations.

The cold-storage business has developed most extensively in the large cities and in towns conveniently located for distributing the fruit later in the season to domestic or foreign markets.

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[a] Bul. Amer. Warehouseman's Ass'n, Nov., 1901, ex N. Y. Sun.

The following table[a] gives a list of the cities and towns in which more than 75,000 barrels of apples were stored about December 1, 1902:

Cities and towns in which more than 75,000 barrels of apples were held in cold storage about December 1, 1902.

Place.	Number of barrels stored.	Place.	Number of barrels stored.
Chicago, Ill	431,700	Boston, Mass., and vicinity	102,000
New York, N. Y	200,000	Indianapolis, Ind	100,000
Philadelphia, Pa., and vicinity	200,000	Leroy, N. Y	100,000
Rochester, N. Y	150,000	Brighton, N. Y	90,000
St. Louis, Mo	120,000	Lockport, N. Y	90,000
		Albion, N. Y	86,000

The extent of the apple-storage business in States in which more than 100,000 barrels were stored about December 1, 1902, is shown in the following table:[a]

States in which more than 100,000 barrels of apples were held in cold storage about December 1, 1902.

State.	Number of barrels stored.	State.	Number of barrels stored.
New York	967,000	Ohio	135,800
Illinois	524,400	Massachusetts	118,000
Missouri	327,000	Indiana	107,500
Pennsylvania	220,000		

Large quantities of apples are still stored in cellars and common storage houses, especially in New York and in the New England States. The extent of this phase of the storage business in States storing 75,000 barrels or more about December 1, 1902, is given in the following table:[a]

Apples in common storage about December 1, 1902.

State.	Number of barrels in common storage.	State.	Number of barrels in common storage.
New York	474,000	Massachusetts	100,000
Maine	240,000	Vermont	75,000
New Hampshire	123,000		

[a] Statistics furnished through the courtesy of the National Apple Shippers' Association.

The magnitude and growth of the apple-storage business as a whole may be better appreciated by reference to the accompanying table, which represents the number of barrels held in the United States both in cold and common storage about December 1 each year since 1898:[a]

Apples in storage about December 1, 1898–1902.

Date.	Barrels in cold storage.	Barrels in common storage.	Date.	Barrels in cold storage.	Barrels in common storage.
1898......	800,000	400,000	1901......	1,771,200	138,000
1899......	1,518,750	634,500	1902......	2,978,050	1,236,750
1900......	1,226,900	794,000			

The approximate number of barrels stored in Canada and Nova Scotia on December 1, 1902, was 437,200 in common storage, and 32,800 in cold storage.

THE FUNCTION OF THE COLD-STORAGE WAREHOUSE.

There is a good deal of misapprehension as to the function of a cold-storage house in the preservation of fruits. This condition leads to frequent misunderstandings between the warehouseman and the fruit storer, though they might be avoided and the condition of the fruit-storage business improved if there was a clearer definition of the influence on fruit preservation of cultural conditions, of the commercial methods of handling, and of the methods of storage.

A fruit is a living organism in which the life processes go forward more slowly in low temperatures, but do not cease even in the lowest temperatures in which the fruit may be safely stored. When the fruit naturally reaches the end of its life it dies from old age. It may be killed prematurely by rots, usually caused by fungi which lodge on the fruit before it is packed, or sometimes afterwards. The cold-storage house is designed to arrest the ripening processes in a temperature that will not injure the fruit in other respects and thereby to prolong its life history. It is designed also to retard the development of the diseases with which the fruit is afflicted, but it can not prevent the slow growth of some of them. It follows that the behavior of different apples or lots of apples in a storage room is largely dependent on their condition when they enter the room. If they are in a dissimilar condition of ripeness, or have been grown or handled differently, or vary in other respects, these differences may be expected to appear as the fruit ripens slowly in the low temperature. If the fruit is already overripe, the low temperature can not prevent its deterioration sooner than would be the case with apples of the same variety that were in a

[a] Statistics furnished through the courtesy of the National Apple Shippers' Association.

less mature condition. If the fruit has been bruised, or is covered with rot spores, the low temperature may retard but can not prevent its premature decay. If there are inherent differences in the apples due to the character of the soil, the altitude, and to incidental features of orchard management, or variations due to the methods of picking, packing, and shipping, the low temperature must not be expected to obliterate them, but rather to retard while not preventing their normal development.

In general it is the function of the cold-storage warehouse to furnish a uniform temperature of the desired degree of cold through its compartments during the storage season. The warehouse is expected to be managed in other respects so that the deterioration of the fruit or any other injury may not be reasonably attributed to a poorly constructed and installed plant, or to its negligent or improper management. The warehouseman does not insure the fruit against natural deterioration; he holds it in storage as a trustee, and in that relation is bound to use only that degree of care and diligence in the management of the warehouse that a man of ordinary care and prudence would exercise under the circumstances in protecting the goods if they were his private property.

If the temperature of the storage rooms fluctuates unduly from the point to be maintained and causes the fruit to freeze to its injury, or to ripen with abnormal rapidity, or if the management of the rooms or the handling of the fruit in other respects can be shown to have been faulty or negligent, the warehouse has failed to perform its proper function.

PRINCIPLES OF MECHANICAL REFRIGERATION.

Refrigeration, or cold storage, as applied to warehouses, is usually produced by the evaporation of a liquefied gas, which in evaporation absorbs the heat from its surroundings, thereby lowering the temperature. The refrigerating gases generally used are anhydrous ammonia, sulphurous acid, and carbonic acid (also known as carbon anhydrid and carbon dioxid). The cold temperature in the warehouses is usually produced by either of two methods, commonly known as the compression and the absorption systems.

The compression system takes its name from the fact that the refrigerating gas—whether ammonia, carbonic acid, or sulphurous acid—is first compressed in a machine called a compressor. Heat is generated by the compression; the gas is then cooled and condensed in pipes or coils called the condenser, either immersed in water or having water running over them, and this converts the gas into a liquid. The liquefied gas then passes an expansion valve to pipes or coils called the refrigerator cooling coils or cooler, where it is evaporated by the heat which is withdrawn from the surroundings. The gas formed by the evaporation of the liquid returns to the compressor, is again condensed, then reevaporated, and the cycle of refrigeration is repeated over and over.

In the absorption system the gas is obtained by heating strong aqua ammonia in a still, thereby driving off the ammonia gas. The gas is then reduced in a condenser to a liquid in a manner similar to the compression system. The liquefied ammonia produces refrigeration by evaporating in the cooling coils, and the gas is then absorbed by weak aqua ammonia in coils called an absorber. The resulting strong liquor is then pumped back to the still. The cycle of refrigeration is repeated continuously, and consists, first, in the generation of a gas by heating strong aqua ammonia in a still; second, in condensing the gas which is deposited from the water to a liquid in the condenser coils; third, in its evaporation to a gas in the cooling or refrigerator coils; fourth, in its absorption by the weak aqua ammonia in the absorber; and fifth, the ammonia liquor is piped to the still and redistilled.

THE UTILIZATION OF THE COLD TEMPERATURES.

There are three general methods of producing the desired temperatures in cold-storage rooms, and these are known as the direct-expansion, the brine-circulating, and the indirect or air-circulating systems. All three systems may be used in a cold-storage plant, and in a given room or compartment the air-circulating system is sometimes used in connection either with the brine or the direct-expansion systems.

THE DIRECT-EXPANSION SYSTEM.

In the direct-expansion system the liquefied gas evaporates directly in the cooling refrigerator coils or pipes which are placed in the refrigerator rooms. The heat used in the evaporation of the gas is absorbed from the room or from its contents, and the temperature is thereby reduced. The gas then returns to the compressor in the compression system, or to the absorber in the absorption system, and after being distilled in the latter case begins the refrigerating cycle anew.

THE BRINE-CIRCULATING SYSTEM.

In the brine-circulating system, the liquefied gas, instead of evaporating directly in coils in the storage room, evaporates in pipes surrounded by brine, or in a brine cooler. The heat used in the evaporation of the gas is absorbed from the brine rather than from the room and its contents, as in the direct-expansion system. The cold brine is then pumped to coils in the storage room and the heat of the room and its contents is absorbed by the cold brine. The warm brine is then returned to the tank or cooler from which it started and is recooled, while the gas returns to the condenser or to the absorber to renew the cycle of refrigeration.

THE AIR-CIRCULATING SYSTEM.

In the indirect or air-circulating system the air in a well-insulated room, which is sometimes called a coil room or a "bunker room," is first cooled, either by the direct-expansion or by the brine-circulating system. The cold air of the coil room is then forced through ducts to the storage rooms. After passing through the storage rooms it is returned by ducts to the coil room to be recooled and purified and to begin the circuit anew.

There are many modifications in the details of these systems when applied to storage houses, but as this publication does not deal primarily with the engineering side of refrigeration it is the purpose to set forth approximately the fundamental principles on which the most common storage systems are based rather than to discuss their application or their respective merits.

OUTLINE OF EXPERIMENTS IN APPLE STORAGE.

An outline of the apple storage experiments of the United States Department of Agriculture is presented here. The following problems have been under investigation during two apple seasons:

(1) A comparative test of the keeping quality of a large number of varieties grown in different regions and of the same varieties grown under different conditions and in different localities.

The fruit has been stored in closed 50-pound boxes in a temperature of 31° to 32° F. One-half of the fruit in each box has been wrapped in paper.

(2) A determination of the influence of various commercial methods of apple handling on the keeping quality of the most important varieties in the leading apple-growing regions of the eastern United States.

Each variety has been picked at two different degrees of maturity: First, when nearly grown but only half to two-thirds colored, or about the time when apples are usually picked; second, when the fruit was fully grown and more highly colored, but still hard. In each picking the fruit was separated into two lots, representing the average of the lightest and of the darkest colored or most mature specimens.

Part of the fruit of each series was sent to storage as soon as picked. A duplicate lot was held two weeks in the orchard or in a building, either in piles or protected in packages, before it was sent to storage.

Comparative tests have been made to determine the efficiency of different kinds of fruit wrappers on the keeping of the fruit, and observations on the behavior of the fruit in closed and ventilated packages have been recorded.

(3) A determination of the influence of various cultural and other conditions of growth on the keeping quality of the fruit.

Comparison has been made with the same variety from heavy clay and from sandy soils, from sod, and from cultivated land, from young, rapidly growing trees, and from older trees with more steady habits.

(4) A determination of the behavior of the fruit under the conditions outlined in temperatures of 31° to 32° F., and in 34° to 36° F.

(5) A determination of the behavior of the fruit when removed from storage, and of its value to the consumer.

The fruit used in the investigations has been taken from central and eastern Kansas, southwestern and central Missouri, southern and central Illinois, western Michigan, northeastern West Virginia, northern and western Virginia, western North Carolina, central Delaware, southern Maine, central Massachusetts, and from eastern, central, and western New York. A description of each orchard accompanies the data included in the account of the variety test. (See pages 34 and 35.)

The fruit has been stored in the following cold-storage houses: Washington Market Company, Washington, D. C.; Reading Terminal Market, Philadelphia, Pa.; Quincy Market Cold Storage Company, Boston, Mass.; Buffalo Cold Storage Company, Buffalo, N. Y.; Western Cold Storage Company, Chicago, Ill.; Twin City Ice and Cold Storage Company, Champaign, Ill., and the Armour Packing Company, Kansas City, Mo.

It has been necessary to duplicate the work in different parts of the country, as the climatic and other conditions and the varieties differ in each section. The work must be repeated for several successive seasons before general conclusions can safely be drawn from it, as the climatic conditions differ each year and thereby affect the results.

FACTORS INFLUENCING THE KEEPING QUALITY OF APPLES.

THE MATURITY OF THE FRUIT WHEN PICKED.

In recent years there has been a tendency to pick the apple crop relatively earlier in the season than formerly. It is quite generally supposed that the longest keeping apples are not fully developed in size or maturity and that the most highly colored fruit is less able to endure the abuses that arise in picking, packing, and shipping.

Aside from these general impressions, several important economic factors have influenced the picking time. A large proportion of the apple crop is purchased in the orchard by the barrel or by the entire orchard by a comparatively few apple merchants. The fruit may be picked and barreled either by the grower or by the purchaser, but with the growing scarcity of farm hands and other labor it has become necessary to begin picking relatively earlier in the autumn to secure the crop before the fall storms or winter months set in.

The general increase in freight traffic during the past few years has overtaxed the carrying capacity of the railroads as well as their terminal facilities for freight handling, and has influenced the apple dealers to extend the picking and shipping season over the longest possible time, in order to avoid congestion and consequent delays in shipping and in unloading the fruit. The facilities at the warehouses are often inadequate for the quick handling of the fruit from the cars when it is received in unusually large quantities, and this condition has also favored a longer shipping season.

In localities where the entire crop is sometimes ruined by the bitter rot after the fruit is half grown the picking of the apples is often begun early in the season in order to secure the largest amount of perfect fruit.

It is not generally the case, however, that the immature and partly colored fruit has the best keeping quality. On the other hand, an apple that is not overgrown and which has attained full growth and high color, like the lower figure of York Imperial in Plate I, frontispiece, but is still hard and firm when picked, equals the less mature fruit (upper figure, Plate I) in keeping quality, and often surpasses it. The mature fruit is superior in flavor and texture; it is more attractive to the purchaser, and therefore of greater money value. It retains its plumpness longer and is less subject to apple scald. If, however, the fruit is not picked until overripe, it is already near the end of its life history, and will deteriorate rapidly unless stored soon after picking in a low temperature.

In the experiments with the Tompkins King and the Sutton apples grown in New York on rapidly growing young trees producing unusually large apples, the fruit that was three-fourths colored kept longer than the fully colored apples from the same trees. Dark red Tompkins King showed 28 per cent of physiological decay in February following the storage. Light, half red Tompkins King from the same trees, picked at the same time, showed 10 per cent of physiological decay in February following the storage. Plate II shows Tompkins King in February at two degrees of color. The fruit represented by the lower specimen had the longer-keeping quality, even though both lots were hard when picked. Whether the same conditions hold true of other varieties that are overgrown has not been determined.

A considerable number of later varieties may be picked when they are beginning to mellow, and will keep for months in prime condition provided they are handled with great care and quickly stored after picking in a temperature of 31° to 32° F. Fruit in this ripe state can not be left in the orchard or in warm freight cars, or in any other condition that will cause it to ripen after picking, without seriously injuring its value. In this ripe condition it should be stored in boxes, and a fruit wrapper will still further protect it.

Apples that are to be stored in a local cold-storage house to be distributed to the large markets in cooler weather may be picked much later than fruit requiring ten days or more in transit, but the use of the refrigerator car makes late picking possible where the fruit must be in transit for a considerable time in warm weather in reaching a distant storage-house.

HOW TO OBTAIN MORE UNIFORM AND BETTER COLORED FRUIT.

While it is not the purpose of this publication to discuss cultural practices in the orchard, some suggestions in relation to the methods of securing more mature and more highly colored fruit may not be without value to the fruit grower.

A large proportion of the poorly colored fruit from old orchards is caused by dense-headed trees and close planting, which prevent the free access of air and sunlight and delay the maturity of the fruit in the fall. The fundamental corrective in such cases lies in judicious pruning, by which means the fruit may be exposed to the sunlight.

In other cases the poor color may be due to a combination of heavy soil, tillage, frequent turning in of nitrogenous cover-crops, spraying, and neglect in pruning. These conditions stimulate the trees to active growth, the foliage increases in health, size, and quantity, and, as the water-holding capacity of the soil is enlarged by the incorporation of the cover-crops and is retained by the tillage, the trees grow late in the fall and the fruit does not properly color before the picking season arrives. It is often possible to overcome the difficulty by severely pruning the top to let in more air and light. If this treatment does not prove efficient, the cover-crops may be withheld, when the fruit will usually mature earlier in the fall, unless the season is wet. As an additional treatment where necessary, the growth of the orchard may be still further checked by seeding it down until the desired condition is attained.

It is not possible to secure a uniform degree of maturity and size when all the apples on a tree are picked at one time, as fruit in different stages of growth is mixed together on the same tree. The apples differ in size and maturity in relation to their position, the upper outer branches producing the large, highly colored and early ripening fruit, while the apples on the side branches and the shaded interior branches ripen later. Greater uniformity in these respects is approached by proper pruning and by other cultural methods, but the greatest uniformity can be attained when, like the peach or the pear, the apple tree is picked over several times, taking the fruit in each picking that approaches the desired standard of size and maturity.

Summer apples, like the Yellow Transparent, Astrachan, and Williams, are usually picked in this manner, and fall varieties, like Twenty Ounce, Oldenburg, and Wealthy, are sometimes treated similarly. In recent years a few growers of winter apples have adopted the plan for the late varieties, with the result that the size, color, and ripeness of a larger proportion of the fruit are more uniform. This method of picking is not usually adapted to the apple merchant who buys the crop of a large number of orchards, and who can not always secure efficient or abundant labor, but for the specialist who is working for the finest trade and who has a storage house near by or a convenient refrigerator car service to a distant storage house, the plan has much to commend it.

INFLUENCE OF DELAYING THE STORAGE OF THE FRUIT.

The removal of an apple from the tree hastens its ripening. As soon as the growth is stopped by picking, the fruit matures more rapidly than it does when growing on the tree and maturing at the same time. The rapidity of ripening increases as the temperature rises, and it is checked by a low temperature. It appears to vary with the degree of maturity at which the fruit is picked, the less mature apples seeming to reach the end of their life as quickly as or even sooner than the more mature fruit. It varies with the conditions of growth, the abnormally large fruit from young trees or fruit which has been overgrown from other causes ripening and deteriorating very rapidly. It differs with the nature of the variety, those sorts with a short life history, like the summer and fall varieties, or like the early winter apples, such as Rhode Island *Greening*, Yellow Bellflower, or Grimes *Golden*, progressing more rapidly than the long-keeping varieties like Roxbury, Swaar, or Baldwin.

Any condition in the management of the fruit that causes it to ripen after it is picked brings it just so much nearer the end of its life, whether it is stored in common storage or in cold storage, while treatment that checks the ripening to the greatest possible degree prolongs it.

The keeping quality of a great deal of fruit is seriously injured by delays between the orchard and the storage house. This is especially true in hot weather and in fruit that comes from sections where the autumn months are usually hot. If the apples are exposed to the sun in piles in the orchard, or are kept in closed buildings where the hot, humid air can not easily be removed from the pile, if transportation is delayed because cars for shipment can not be secured promptly, or if the fruit is detained in transit or at the terminal point in tight cars which soon become charged with hot, moist air the ripening progresses rapidly and the apples may already be near the point of deterioration or may even have commenced to deteriorate from scald, or mellowness, or decay when the storage house is reached.

On the contrary, the weather may be cool during a similar period of delay and no serious injury result to the keeping quality, or the ripening may be checked in hot weather by shipping the fruit in refrigerator cars to a distant storage house.

The fungous diseases of the fruit, such as the apple scab (*Fusicladium dendriticum* (Wallr.) Fckl.) and the pink mold (*Cephalothecium roseum* Cda.) which grows upon the scab, the blue mold (*Penicillium glaucum* Link) which causes the common, soft, brown rot, the black rot (*Sphaeropsis malorum* Pk.), and the bitter rot (*Gloeosporium fructigenum* Berk.) develop very fast if the fruit becomes heated after picking. The conditions already enumerated which cause the fruit to ripen quickly during the delay between the orchard and the storage house are also most favorable to the development of fruit diseases. It is therefore of the greatest importance that the fruit be stored immediately after picking, if the weather is warm, in order to insure it against the unusual development of the fungous rots.

In the fall of 1901, when the weather in western New York was cool, there was no apparent injury from delaying the storage of a large number of varieties two weeks and then shipping the fruit to Buffalo, the transit occupying from one to three days. There was also no apparent injury to the fruit from Virginia treated in a similar manner, but in southwestern Missouri, where it was warmer, the apples delayed two weeks before storing were seriously injured in their commercial keeping qualities.

The results accomplished during 1902 have been of the most instructive character. During the later half of September the temperature in eastern New York averaged about 62° F., with a humidity of 84°. During the first half of October the average temperature was 53° F. and the humidity 80°.

Rhode Island *Greening*, Tompkins King, and Sutton apples picked September 15, 1902, and stored within three days, were firm till the following March, with no rot or scald, but fruit from the same trees not stored till two weeks after picking was badly scalded or decayed by the 1st of January. None of the immediate-stored fruit was scalded or decayed by the 1st of February, but the delayed Sutton and Rhode Island *Greening* apples were soft and mealy, and one-third were scalded at that time, while nearly 40 per cent of the delayed Tompkins King were soft and worthless. The commercial value of these varieties was injured from 40 to 70 per cent by the delay in storage.

Apples of these varieties picked from the same trees on October 5, 1902, and stored immediately, and also some stored two weeks later, were less injured by the delay, as the temperature and humidity were not sufficiently high to cause rapid ripening or the development of the fruit rots.

From the standpoint of the orchardist or apple dealer who can not secure quick transportation to the large storage centers, or who can not obtain refrigerator cars, or who is geographically situated where the weather is usually warm in apple-picking time, the local storage plant in which the fruit can be stored at once and distributed in cool weather offers important advantages. The importance of this phase of the fruit-storage business and its relation to the fruit-growing industry are emphasized as the apple business enlarges.

INFLUENCE OF STORAGE TEMPERATURE.

The investigations indicate that the ripening processes are delayed more in a temperature of 31° to 32° F. than in 35° to 36° F. The apple keeps longer in the lower temperature, it scalds less, the fruit rots and molds are retarded to a greater extent, while the quality, aroma, flavor, and other characteristics of the fruit are fully as good, and when removed from storage it remains in good condition for a longer period.

The impression is quite general that fall varieties and the tender early winter sorts, like Fameuse, Wealthy, and Grimes, are injured in some way by the low temperature, but the investigations of the Department of Agriculture indicate that these varieties behave more satisfactorily in every respect when stored at 31° to 32° F.

If the fruit is intended for storage for a short time only, and it is desired to have it ripen before removing it from the storage house, then a higher temperature may be desirable to hasten the maturity.

The influence of the temperature on the ripening processes appears to depend on the condition of the fruit. Baldwin, Esopus *Spitzenburg*, Roxbury, Jonathan, Lady Sweet, and other long-keeping eastern-grown varieties have been held in prime commercial condition throughout the storage season in a temperature of 35° F. when carefully picked and handled and stored soon after picking; but when the fruit was carelessly handled or the storage was delayed in hot weather, then a temperature of 31° to 32° F. was required to retard the ripening.

It might be safe to use a temperature of 34° to 35° F. in a storage house located near the orchard, in which the fruit may be stored immediately after harvesting, but for general commercial apple handling, a temperature as low as 32° F. is needed to overcome the abuses that usually arise in picking, packing, and shipping.

No definite investigations have been made by the Department of Agriculture as to the effect of temperatures lower than 31° F. The exact freezing point of apples has not been determined, but it is below this point. It may possibly vary with the composition or condition of the variety. Under the most favorable conditions, apples are sometimes commercially stored at 30° F. without injury, but 31° F. should be considered a critical temperature below which it is unsafe to store this fruit, except in houses that are properly constructed and in which the temperature is maintained uniform in all parts of the rooms.

Apples are sometimes frozen in the storage rooms owing to a considerable drop in the temperature or to a poor distribution of the cold air. If the fruit compartment adjoins a freezer room and the insulation is poor, the fruit may be frozen in packages piled close to the freezer wall. Apples placed near the refrigerating pipes or near the cold-air duct where it enters the room may be injured by freezing if the plant is improperly installed or managed; or if the piping or air circulation is faulty, the temperature at the bottom may be lower than that at the top of the room.

The frosting of the fruit does not necessarily injure it. When the apple freezes, the water in the cells is withdrawn and frozen in the intercellular spaces, and if it thaws slowly and the freezing has not been too severe, the cells may regain the water without injury and resume their living function. If the thawing is rapid, the cells may not reabsorb the water with sufficient rapidity, and in this case it remains in the intercellular spaces and is lost by evaporation. In addition, the tissues next to the area of greatest freezing may be forced apart by the formation of ice crystals in the intercellular spaces.

If the freezing is so severe as to withdraw too much of the cell water, the cells may not be able to absorb it and will be killed in the same manner as if dried out in any other way. Occasionally the freezing is so rapid that besides the withdrawal of water the cell contents are disorganized or possibly frozen outright; at any rate, the cell may be directly killed by a sudden change of temperature. It is probable that varieties may differ as to the degree of freezing they will stand without injury, and further, that the same sort may vary in this respect when grown under different conditions or subjected to different treatment.

The most characteristic results of injurious freezing are a translucent appearance of the skin of the fruit, a water-logged and springy or spongy condition of the flesh, a forcing apart of the tissues, and a brownish discoloration of the flesh. The browning may result from any cause which results in the death of the cells and is not necessarily characteristic of freezing. It often happens that the skin of the fruit retains its normal brightness after the interior has discolored.

In the practical handling of frozen stock, the temperature should be raised very slowly until the frost is withdrawn. If possible, the fruit should not be moved until it is defrosted, as it discolors quickly wherever a slight bruise occurs or even where the skin is lightly rubbed. With these precautions observed it is often possible to defrost stock that is quite firmly frozen without apparent injury to it.

INFLUENCE OF A FRUIT WRAPPER.

In the storage investigations under discussion a comparison has been made between wrapped and unwrapped stock on the keeping quality of the fruit, and the efficiency of different kinds of paper for wrappers—tissue, parchment, waxed or paraffin, and unprinted news—has been tested. A box of unwrapped fruit, with packages of fruit wrapped with the kinds of paper mentioned in order above, is shown in Plate III, fig. 1.

It has been found that the wrapper may influence the keeping quality in several different ways. It extends the life of the fruit beyond its normal period by retarding the ripening processes. The influence of the wrapper in this regard is apparent especially at the end of the normal storage season of the naked fruit when the flesh begins to grow mealy from overripeness. At this time the wrapped apples may be firm and remain in prime condition for several weeks or even months. The wrapper is especially useful in extending the season of early winter sorts, or in making the long-keeping varieties available for use over a still longer period of time.

The wrapper may be useful in preventing the transfer of rot from one apple to another. If the fungus is capable of growing in the storage temperature, it is not likely that the wrapper retards its growth. but when the spores develop they are confined within the wrapper and their dissemination is difficult or impossible.

The importance of a wrapper in protecting the fruit from decay and in extending its season may be better appreciated by reference to the following:

Amount of decayed fruit April 29, 1903, in bushel packages.

Variety.	News paper wrapped.	Unwrapped.	Variety.	News paper wrapped.	Unwrapped.
	Per cent.	*Per cent.*		*Per cent.*	*Per cent.*
Baker	3.7	27.2	Northern Spy	5.6	52.0
Dickenson	6.4	43.0	Wagener	38.0	63.0
McIntosh	7.7	15.0	Wealthy	42.0	60.0
McIntosh (second lot)	19.7	32.0			

The wrapper protects the apple against bruising and the discoloration that may result from improper packing or rough handling; it checks transpiration, and by the preservation of the attractive appearance and firmness of the fruit adds to its commercial value.

No important difference was noticeable in the efficiency of the different wrappers, except that a mold developed freely on the parchment paper in a temperature of 36° F. This mold grew only to a slight extent in 32° F.

A double wrapper is more efficient in retarding ripening and transpiration than a single wrapper. A good combination consists in a porous news paper next to the fruit, with an impervious wax or paraffin wrapper on the outside. The wrappers vary in cost from 20 cents per thousand for news paper, 9 x 12 inches, to 70 cents per thousand for the better grades of paraffin.

INFLUENCE OF CULTURAL CONDITIONS.

Preliminary studies have been made on the influence of cultural and other conditions surrounding the growing fruit on its storage quality.

Considerable data along this line will be brought out in the comparison of the same variety grown in different sections. It has been observed that the Tompkins King, Hubbardston, and Sutton apples from rank-growing young trees ripen faster than smaller fruit from older slower-growing trees, and therefore reach the end of their life history sooner. From older trees these varieties have kept well till the middle of April, while from young trees the commercial storage limit is sometimes three months shorter.

It has been noticed that Rhode Island *Greening* apples from old trees remain hard longer than the same variety from young trees, but the greener condition of the fruit from the older trees when picked at the same time made it more susceptible to scald. Rhode Island *Greenings* from Mr. Grant G. Hitchings, South Onondaga, N. Y., showed 50 per cent of scald from young trees on April 28, 1903, and 82 per cent in smaller, greener fruit from older trees.

Rhode Island *Greening*, Mann, and Baldwin apples grown on sandy land ripened more rapidly than similar fruit from clay land, where all of the other conditions of growth were similar. Plate IV shows the average condition of Baldwin apples on April 28, 1903, grown on sandy and clay soil in the orchard of Mr. W. T. Mann, Barker, Niagara County, N. Y., and stored in a temperature of 32° F. The upper apple was grown on clay; the lower, on sandy soil.

The subject will require critical study over a period of years before it will be possible to fully understand the influence of various cultural, climatic, and other conditions of growth on the life processes in the fruit.

INFLUENCE OF THE TYPE OF PACKAGE.

The principal storage packages for apples are barrels of about 3 bushels capacity and boxes holding 40 to 50 pounds. The larger the bulk of fruit and the more it is protected from the air the longer it retains the heat after entering the storage room. If the fruit is hot and the variety a quick-ripening sort, it may continue to ripen considerably in the center of the package before the fruit cools in that position. The long-keeping varieties that are harvested and shipped in cooler weather are less likely to show the effect of the type of the package. The smaller package therefore presents distinct advantages for the early, quick-ripening varieties and is most useful in the hottest weather, as the fruit cools down quickly throughout the package and its ripening proceeds uniformly.

There is a wide difference of opinion concerning the comparative value of ventilated and closed packages for apple storage. The chief advantage of the ventilated package appears to lie in the greater rapidity with which its contents cool off, and its value in this respect depends on the amount of ventilation in the package. The contents of an ordinary ventilated apple barrel do not cool much more quickly than the contents of a closed barrel, and the value of the ventilated barrel for the purpose for which it is designed is somewhat doubtful.

Apples in a ventilated package are likely to shrivel if the fruit is stored for any length of time. In the ordinary ventilated apple barrel the exposure is not sufficient to affect the fruit to any extent, but in boxes in which there is much exposure the fruit may be corky or spongy in texture if held until spring.

The size of the package may have an important influence on the length of the storage season. Its influence in this respect is especially marked when the fruit begins to mellow in texture. Barrel stock in this condition needs to be sold to prevent the bruising of the fruit from its own weight, but apples equally ripe may be carried in boxes safely sometimes for several weeks longer.

THE BEHAVIOR OF THF FRUIT WHEN REMOVED FROM STORAGE.

There is a general impression that cold-storage apples deteriorate quickly after removal from the warehouse. This opinion is founded on the experience of the fruit handler and the consumer, but the impression is not generally applicable to all storage apples. In fact, it is probable that storage apples do not deteriorate more quickly than other apples that are equally ripe and are held in the same outside temperature. If the fruit is overripe when taken from storage—and a good deal of stock is stored until it reaches this condition—it naturally breaks down quickly; but firm stock may be held for weeks and even months after it has been in storage.

The rapidity of deterioration depends also on the temperature in which the fruit is removed. The following table shows the amount of decay in Baldwin apples from the same barrel after removal and subjection to different temperatures:

Amount of decay after removal from storage to different temperatures.

Variety.	Date removed from storage (1903).	Date inspected.	Per cent rot.			
			44° F.	48° F.	61° F	67° F.
Baldwin	Jan. 29	Jan. 29	0	0	0	0
		Feb. 10	0	0	3	10
		Feb. 13	0	0	12	14
		Feb. 16	0	0	21	24
		Feb. 20	0	4	23	28
		Mar. 3	5	10	....	....
		Mar. 7	5	15	....	....
		Mar. 21	20	....	....	....
		Apr. 6	36	....	....	....

Late in the spring the fruit is far advanced in its life and the weather is becoming warmer. All apples similarly ripe, whether in cold storage or not, break down more quickly at this time than in the winter.

In commercial practice the dealer often holds the apples for a rise in price, and finally removes them from the warehouse, not because the market has improved, but for the reason that he finds that a longer storage would result in serious deterioration from fruit rots and over-ripeness. When a considerable amount of stock is decayed on removal from the warehouse the evidence is conclusive that the apples should have been sold earlier in the season. In the purchase of cold-storage stock the consumer will have little cause to complain of the rapid deterioration of the fruit if he exercises good judgment in the selection of apples that are still sound and firm.

THE IMPORTANCE OF GOOD FRUIT.

Apples do not improve in grade in cold storage. In handling a crop too much care can not be given to grading the fruit properly before it enters the storage house. The contents of many packages are injured by the spread of disease from a few imperfect apples. Rots enter the fruit most easily wherever the skin is bruised or broken, and in the early stages of the rot development it is common to see the diseases manifesting themselves around worm holes or bruises occasioned by rough handling, from nails that protrude through the barrels, or from other causes.

When the crop is light it may pay to store apples that are not of the first grade, but such fruit should be rigidly eliminated from the best stock and stored where it can be removed earlier in the season than the better qualities.

The attractiveness and the value of the best fruit is often injured by careless handling. A bruised spot dies and discolors. Finger marks made by pickers, graders, and packers, and injuries from the shifting of the fruit in transit or from rough handling, become more apparent as the season advances. In fact, all of the investigations of the Department of Agriculture emphasize the fundamental importance of well-grown, carefully handled fruit in successful storage operations.

Plate III, fig. 2, shows a barrel of Northern Spy apples poorly packed. On the right is shown a barrel of Esopus well packed. A great deal of fruit is taken from storage "slack," the fruit not being firmly packed in the barrels in the orchard.

APPLE SCALD.

When some varieties of apples reach a certain degree of ripeness the part of the fruit grown in the shade often turns brown, not unlike the color of a baked apple. This difficulty does not extend deep into the flesh, but it detracts from the appearance of the fruit and reduces its commercial value. This trouble is commonly called "apple scald." It may appear in fruit held in common or in cold storage.

The exact nature of scald is not well understood, though apple men have many theories by which its appearance is popularly explained. The most common theory gives rise to the name of scald—that is, the brown, cooked appearance is thought to be due to the overheating of the fruit when it is stored, or to a temperature too low for the variety, or to picking the fruit when too ripe; and other matters relating to the growth and handling of the fruit are thought to develop it.

As the scald is an important commercial problem it has been considered from several standpoints in the fruit-storage investigations of the Department. The nature of the scald, the influence of the degree of maturity of the fruit when picked, of commercial methods of handling, of fruit wrappers, of different temperatures, and of cultural conditions on its development are among the problems investigated.

NATURE OF THE SCALD.

Apple scald is not a contagious disease. According to Dr. A. F. Woods, Pathologist and Physiologist of the Department of Agriculture, it is a physiological disturbance not connected in any way with the action of parasitic or saprophytic organisms such as molds or bacteria. Briefly, it is the mixing of the cell contents or premature death of the cells and their browning by oxidation through the influence of the normal oxidizing ferments of the cell. There are many conditions which influence the development of this trouble. It appears to be closely connected with the changes that occur in ripening after the fruit is picked, and is most injurious in its effects as the fruit approaches the end of its life. Several of the factors that influence it will be discussed. Plate V shows the scald on a Rhode Island *Greening* apple. The cross section shows that scald does not extend deep into the flesh.

INFLUENCE OF MATURITY OF THE FRUIT ON SCALD.

The scald always appears first on the green or less mature side of an apple, and if the fruit is only partly ripe it may spread entirely over it; but the portions grown in the shade and undercolored are first and most seriously affected. The upper figure in Plate I (frontispiece) shows the distribution of scald on an immature York Imperial apple. The apples that are more mature and more highly colored when picked are less susceptible to injury, and the side grown in the sunlight may remain entirely free from it. The lower figure in Plate I shows a well-colored York Imperial apple and its freedom from the scald is noticeable.

When the apple crop is picked before it is mature the fruit is more susceptible to scald than it would have been later in the season. The relative susceptibility of immature and more mature apples is brought out in the table following. The fruit was picked two weeks apart. At the first picking the apples were partly colored, or in the condition in which a large proportion of the commercial apple crop is harvested. At the second picking the fruit was more mature, with better color, but still hard. The differences in ripeness are fairly represented in the fruit on Plates I and II. The percentages do not represent the relative susceptibility of the different varieties to scald, as the fruit was grown in different States and the observations were made at different times. The percentages show the average amounts of scald in fruit stored at temperatures of 31° to 32° F. and 34° to 36° F.

Scald on mature and immature apples.

Variety.	Locality grown.	Mature, well colored.	Immature, partly colored.
		Per cent.	*Per cent.*
Baldwin	New York	3.1	29.2
Ben Davis	Illinois	2.6	15.8
Do	Virginia	13.1	41.6
Rhode Island *Greening*	New York	25.4	43.4
Winesap	Illinois	0.2	31.8
Yellow Newtown	Virginia	2.3	9.4
York Imperial	do	2.0	18.2
Average		6.9	27.0

In the practical handling of orchards the fundamental corrective of scald lies in practicing those cultural and harvesting methods that develop maturity and a highly colored fruit. These methods have already been briefly discussed. The picking of the fruit when too green, dense-headed trees that shut out the sunlight, heavy soil, a location or season that causes the fruit to mature later than usual and makes it still green at picking time—these are among the conditions that make it particularly susceptible to the development of the scald.

After the fruit is harvested its susceptibility increases as its ripening progresses. Early in the storage season the scald may not appear, but later the same variety may have developed enough to injure its commercial value. The amount of scald at different periods of the season on the same lot of Baldwin apples stored at 32° F. is brought out in the following statement:

Amount of scald at different periods of storage season.

	Per cent.
January 29, 1903	0
February 21, 1903	0
March 20, 1903	20
April 21, 1903	23

It should be the aim of the apple storer to remove the fruit from storage before a variety normally begins to scald and to hold until late in the season only those sorts that do not scald.

INFLUENCE OF TEMPERATURE ON SCALD.

The temperature that checks the ripening to the greatest degree also retards the appearance of the scald. In some of the apple-growing sections it is quite generally believed that bad scalding varieties should be stored in a temperature of 36° to 38° F., and that a temperature as low as 32° F. hastens its development. The investigations of the Department have shown that this impression is not well founded, but on the contrary they indicate that the scald develops more freely in the higher temperature. To illustrate, one lot of York Imperial apples, a variety which is greatly affected by scald, had developed 16.9 per cent of this trouble by January 22, 1902, in a temperature of 36° F., while a similar lot stored in a temperature of 32° F. developed only 3.4 per cent. One lot of Rhode Island *Greening* apples by February 3, 1903, had developed 21 per cent in 32° F., while a similar lot, in 36° F., showed 55 per cent. In the case of the Sutton apple, investigation showed 25 per cent of scald in apples stored at 32°, and 42 per cent where the temperature was kept at 36°.

If the fruit is stored as soon as it is picked, or is shipped in refrigerator cars or in cool weather, and if it has been handled in the most careful manner, the ripening may not proceed much more rapidly and the scald may not develop more freely in the higher than in the lower storage temperature.

THE TEMPERATURE IN WHICH THE FRUIT IS REMOVED FROM THE STORAGE-HOUSE.

When the fruit is removed from the storage-house the scald sometimes develops rapidly. Its appearance at this time seems to depend on at least two important conditions—the ripeness of the fruit and the temperature into which it is taken. Late in the storage season the scald is most severe: first, because the fruit is more mature, and, second, for the reason that the warm weather prevailing at that season develops it quickly.

The development of the scald also seems to be influenced by the amount of humidity in the air. So long as the fruit remains cold and condenses the moisture of the atmosphere upon it the scald is retarded more than in a dry air of the same temperature.

The accompanying table shows the rapidity with which the scald may develop on Baldwin apples when portions of the same barrel are removed to different temperatures. There was no increase in the amount of scald in any of the lots after nine days.

Scald developed in different temperatures when apples were removed from storage.

Variety.	Date removed from storage.	Date inspected.	Per cent of scald.			
			44° F.	48° F.	61° F.	67° F.
	1903.	1903.				
Baldwin	Jan. 29	Jan. 29	0	0	0	0
Do	do	Feb. 3	0	6	21	22
Do	do	Feb. 4	4	11	21	37
Do	do	Feb. 6	4	25	40	63
Do	do	Feb. 7	4	25	41	63

The upper figure in Plate VI shows the average condition of a lot of Wagener apples in March, 1903, when removed from storage; the lower figure, the average condition of the same fruit forty-eight hours later in a temperature of 70° F.

It should be the aim of the fruit s orer not only to remove the fruit before the scald normally appears, but to hold the apples after removal in the lowest possible temperature to prevent its rapid development.

INFLUENCE ON SCALD OF DELAYING THE STORAGE OF THE FRUIT AFTER IT IS PICKED.

The ripening of the fruit between the time of picking and its storage increases its susceptibility to scald.

When the picking and shipping seasons are cool and dry it may be possible to delay the storage of the fruit for some time without injury so far as the predisposition to scald is concerned. In the investigations of 1901–2 in western New York there was no apparent injury from delaying the storage, but the weather conditions at this period were ideal for apple handling.

The scald develops seriously when the storage of the fruit is delayed in hot weather. Detentions in the orchard, in transit in closed cars, in unloading at the terminal, or in the warehouse cause the fruit to ripen quickly and favor the rapid growth of the fruit rots, as they bring the fruit much nearer the end of its life before it enters the storage room. Under these circumstances the fruit may scald badly, mellow early in the season, and rot, and no storage treatment can correct the abuses to which it has been subjected.

The following table brings out the injury that may be caused by delaying the storage of the fruit in hot weather. The mean average temperature between September 15 and 30, 1902, was about 62° F. and the mean average humidity about 84%. Fruit picked from the same trees on October 4, 1902, and stored two weeks later, when the temperature was about 53° F. and the humidity about 80%, was not injured by the delay. The apples referred to were grown in eastern New York and stored in Boston, and these records were taken the following February.

Scald on immediate- and delayed-stored apples in February, 1903.

Variety.	Picked Sept. 12, 1902; stored Sept. 15.	Picked Sept. 15; stored Sept. 30.	Picked Oct. 4; stored Oct. 9.	Picked Oct. 5; stored Oct. 19
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Rhode Island *Greening*	0	38	(No record)	(No record)
Sutton	0	33	0	0
Tompkins King	0	15	0	0

INFLUENCE OF A FRUIT WRAPPER ON SCALD.

The influence of the various fruit wrappers mentioned has been studied in connection with the scald. Sometimes the wrappers retard it to a slight degree, but often the trouble is as severe or more severe in the wrapped fruit. Whenever the wrapper has been effective in retarding the scald the wax or paraffin paper was most useful.

The following table gives a comparison between wrapped and unwrapped fruit; and emphasizes the fact that for commercial purposes the wrapper should not be looked upon as an effective means of preventing the trouble. The records of each variety are based on 8 to 32 bushels of fruit, one-half of which was wrapped.

Scald on wrapped and unwrapped fruit.

Variety.	Locality.	Wrapped.	Unwrapped.
		Per cent.	*Per cent.*
Baldwin	New York	12.4	19.9
Ben Davis	Illinois	5.8	2.8
Do	Virginia	27.1	28.7
Huntsman	Illinois	47.8	40.3
Minkler	do	22.9	20.1
Rhode Island *Greening*	New York	32.3	37.6
Winesap	Virginia	30.0	47.0
Do	Illinois	17.9	10.2
York Imperial	Virginia	9.6	12.9

VARIETIES MOST SUSCEPTIBLE TO SCALD.

All varieties are not equally susceptible to scald, and there appears to be a wide difference in the amount developed in the same variety grown in different parts of the country. While the light-colored portion of an apple is more susceptible than the more highly-colored part, it does not follow that green or yellow varieties are more susceptible than red ones. Of the important commercial sorts used in the investigations of the Department of Agriculture, the varieties named in the subjoined list have proved most susceptible. The season when the scald is most likely to appear is given with each kind, though there may be a wide variation from year to year. The time of the appearance of the scald is influenced to an important degree by the method of handling the fruit and by its degree of ripeness. A larger number of varieties showing scald to a slight extent will be found mentioned in the notes in the variety catalogue.

Arctic, serious, midwinter.
Arkansas, often serious, after midwinter.
Baldwin, often serious, late in season.
Ben Davis, often serious, late in season.
Gilpin, often serious, late in season.
Green Newtown, slight, late in season.
Grimes, serious, early winter.
Huntsman, serious, midwinter.
Lankford, serious, midwinter.
Nero, serious, midwinter.
Paragon, sometimes serious, midwinter.
Ralls, slight, midwinter.
Rhode Island *Greening*, serious, midwinter.
Smith *Cider*, serious, early winter.
Stayman Winesap, sometimes serious, midwinter.
Wagener, serious, midwinter.
White Doctor, serious, midwinter.
White Pippin, slight, late in season.
Willow, slight, late in season.
Winesap, often serious, late in season.
Yellow Newtown, slight, late in season.
York Imperial, serious, midwinter.
York Stripe, slight, late in season.

TREATMENT TO PREVENT SCALD.

Through the cooperation of the Bureau of Chemistry and the Office of Vegetable, Pathological, and Physiological Investigations, of the Department of Agriculture, preliminary studies have been undertaken to determine the influence of various gases and other forms óf treatment on the development of the scald on Ben Davis apples picked in Illinois in August, 1902. The fruit was kept in cold storage till used in the experiments in 1903, when some was slightly scalded. Different lots were placed under the following conditions. The result of the treatment on the scald and fruit is briefly stated in each case.

(1) In air containing formaldehyde vapor. No effect.

(2) In air containing a large amount of sulphur dioxid. Fruit injured.

(3) In air containing one one-hundredths volume sulphur dioxid. No effect on scald, but fruit injured in spots.

(4) In air containing chlorin. Fruit injured around lenticels and scald not prevented.

(5) In air containing alcohol vapor. Fruit uninjured; scald not prevented.

(6) In air containing ether vapor. Fruit uninjured; scald not prevented.

(7) In air containing chloroform vapor. Fruit killed.

(8) In air containing turpentine vapor. Fruit injured; scald not prevented.

(9) In atmosphere of moist oxygen. Fruit uninjured; scald developed more rapidly than in pure air.

(10) In atmosphere of moist nitrogen. Scald entirely prevented, and fruit apparently normal at end of nine days.

(11) Fruit placed in water. Scald retarded; fruit uninjured.

(12) Paraffin over fruit. Scald slightly retarded; fruit uninjured.

(13) Vaseline over fruit. Scald somewhat retarded; fruit uninjured.

(14) Olive oil over fruit. Scald somewhat retarded; fruit uninjured.

It will be seen from the brief outline that the fruit may be injured by some of the gases and that nitrogen was the only gas that prevented scald without injuring the fruit. It is reasonable to assume that a continuation of the fruit in nitrogen gas for a much greater length of time would be injurious, as oxygen is essential to the vital processes. It will be noticed, also, that oxygen stimulated the development of the scald probably by making the conditions favorable for the rapid progress of the scald-producing ferment.

COMPARISON OF VARIETIES IN COLD STORAGE.

A large number of varieties of apples grown under various conditions have been under observation by the Department of Agriculture. It has been the purpose of the investigation to determine the keeping quality of the varieties during the commercial apple-storage season, which usually terminates May 1 or shortly afterwards. It has not been attempted to carry the varieties longer than the apple-storage season, though many of them when finally taken from the storage house have been in prime condition and would have kept well for a longer period.

There is a wide difference in the keeping quality of the same variety when it is grown in different parts of the country. There is a striking variation also in the behavior of the same variety when it is grown in the same locality under different cultural conditions and in different seasons. There may be a permanent difference in the keeping quality of the apples of one region when compared with those of another, but it is not safe to draw general conclusions in this regard until the varieties of each have been under observation during several seasons and have been grown under different cultural conditions. No attempt has been made in these investigations to draw comparisons between the keeping quality of the same sort from different places. The behavior of each lot is given in commercial terms rather than in detailed notes, so that the grower or apple handler may know something of the storage value of a variety under the conditions in which it has been observed by the Department of Agriculture. The fruit has been stored in bushel boxes in a temperature of 30° to 32° F.

The Department had the cooperation of the Kansas, Maine, New York State, and Virginia agricultural experiment stations in 1901 and of the Massachusetts Agricultural College and the New York

State experiment stations in 1902 to the extent of receiving gratuitously fruit of the varieties credited to them in the variety catalogue. It had the cooperation during the season of 1901–2 of the experiment station of the University of Illinois in inspecting and making record of the condition of the fruit stored at Champaign, Ill., especially a times when it could not be conveniently inspected by the representatives of the Department.

OUTLINE OF CULTURAL CONDITIONS.

A statement follows, summarizing the orchard conditions in which the fruit used in the experiments of the Department of Agriculture was grown. In the variety catalogue each sort is credited to the grower from whom it was received:

Boggs, A. H., Waynesville, Haywood County, N. C., 1902:
Clay loam, stony, with clay subsoil; altitude, 3,000 to 3,500 feet; trees, 12 to 15 years old; thoroughly sprayed; sod culture.

Bradley, F. L., Barker, Niagara County, N. Y., 1902:
Sandy loam, with clay subsoil; altitude, about 300 feet; sprayed; tillage; on Lake Ontario.

Brown, J. E., Wilson, Niagara County, N. Y., 1901:
Sandy loam, with sandy loam subsoil; altitude, about 300 feet; trees, 40 years old; sprayed; tillage; on Lake Ontario.

Derby, S. H., Woodside, Kent County, Del., 1902:
Sandy, with clay-loam subsoil; altitude, about 60 feet; trees, 10 to 25 years; thorough spraying and tillage; annual use of clover cover crops; trees unusually vigorous.

Dodd, G. J., Greenwood, Jackson County, Mo., 1902:
Black prairie soil, with clay subsoil; altitude, 1,000 feet; trees, 18 years old, except Ben Davis, 11 years; sprayed; sod culture after trees were 7 years old.

Dunlap, H. M., Southern Illinois, 1901:
Fruit from orchards in southern Illinois; data not available.

Flournoy, W. T., Marionville, Lawrence County, Mo., 1902:
Heavy clay, with rocky limestone clay subsoil; altitude, about 1,250 feet; age of trees, 7 years; spraying and tillage.

Gilbert, Z. A., Farmington, Franklin County, Me., 1902:
Granite drift, with so-called pin-gravel subsoil; altitude, about 365 feet; age of trees, 20 years; no spraying or tillage; land top dressed with wood ashes.

Hitchings, Grant G., South Onondaga, Onondaga County, N. Y., 1901 and 1902:
Clay loam, stony, with heavy red clay or gravel-and-clay subsoil; altitude, about 1,200 feet; age of trees, 4 to 100 years; sprayed; sod culture, with grass left in orchard for mulch.

Hutchins, Edward, Fennville, Allegan County, Mich., 1902:
Clay loam; altitude, 700 feet; age of trees, about 35 years; sprayed; tillage.

Kansas Agricultural Experiment Station, Manhattan, Riley County, Kans., 1901:
Clay loam, with clay subsoil; altitude, about 1,000 feet; age of trees, 10 years; spraying and tillage.
Orchards near the experiment station, 1901: Soil and altitude same as above; no spraying or tillage; fruit received through Kansas Station.

Lupton, S. L., Winchester, Frederick County, Va., 1901 and 1902:
Clay loam, with red clay subsoil; altitude, 750 feet; age of trees, 8 years; sprayed; sod culture, grass cropped.

Maine Agricultural Experiment Station, Orono, Penobscot County, Me., 1901:.
Sandy loam, with clay subsoil; altitude, about 150 feet; age of trees, 10 to 12 years; sprayed; clean culture, with fall cover crop of rye.

Mann, W. T., Barker, Niagara County, N. Y., 1902:
Clay loam, with clay subsoil, and sandy loam with sandy subsoil; altitude, about 300 feet; age of trees, about 30 years; sprayed thoroughly; tillage; clover cover crops.

Massachusetts Agricultural College Experiment Station, Amherst, Hampshire County, Mass., 1902:
Gravelly soil, with clay subsoil, moist; altitude, 250 feet; age of trees, 30 years; sprayed; tillage.

Michigan Agricultural College Experiment Substation, South Haven, Van Buren County, Mich., 1902:
Rich, sandy loam, with clay subsoil; age of trees, 9 to 14 years; altitude, 625 feet; on Lake Michigan; spraying and cultivation thorough.

Miller, W. S., Gerrardstown, Berkeley County, W. Va., 1901:
Soapstone, derived from Romney shale, clay subsoil; altitude, 700 feet; age of trees, 12 to 26 years; sprayed and cultivated.

New York State Experiment Station, Geneva, Ontario County, N. Y., 1901 and 1902:
Rather heavy clay loam, with heavy clay subsoil; altitude, about 600 feet; age of trees, generally from 15 to 25 years; sprayed, and cultivated with cover crops.

Ozark Orchard Company, Goodman, McDonald County, Mo., 1901 and 1902:
Flinty clay, with clay, shale, or gravel subsoil; altitude, 1,250 feet; age of trees, 6 years; sprayed and cultivated.

Powell, George T., Ghent, Columbia County, N. Y., 1902:
Gravelly loam, with clay-gravelly subsoil; altitude, about 400 feet; age of trees, 35 to 45 years, except Tompkins King and Lady Sweet 11 years, Sutton 8 years, Hubbardston 5 years; spraying and cultivation thorough, with clover cover crops annually.

Reeks, M., Douglas, Allegan County, Mich., 1902:
Clay loam, with clay subsoil several feet below surface; age of trees, 12 to 15 years; sprayed and cultivated; altitude, 650 to 675 feet.

Spohr, G. E., Manhattan, Riley County, Kans., 1901:
Sandy loam, with sandy subsoil; altitude, about 950 feet; age of trees, about 20 years, except Jonathan 10 years; no tillage or spraying; fruit received through Kansas Experiment Station.

Speakman, F. H., Neosho, Newton County, Mo., 1901:
Clay loam, gravelly and stony, with red clay subsoil, mixed with flint stone; altitude, 1,100 feet; age of trees, 12 years; sprayed and cultivated.

Taylor, J. F., Douglas, Allegan County, Mich., 1902:
Sandy loam, with clay subsoil 15 feet below surface; altitude, 650 to 675 feet; from 8-year top grafts on stocks of "Cannon Redstreak," 25 years old; sprayed and cultivated.

Virginia Agricultural Experiment Station, Blacksburg, Montgomery County, Va., 1901:
Rather heavy, mostly of limestone origin, with some sand, not stiff, subsoil of same nature but heavier; altitude, 2,170 feet; age of trees, 12 years; sprayed but not cultivated in 1901.

Wellhouse, F., Tonganoxie, Leavenworth County, Kans., 1901:
Rich prairie loam, with red clay subsoil, with some sand; altitude, about 900 feet; age of trees, 7 years; not sprayed but cultivated.

VARIETY CATALOGUE.

[In this catalogue the leading names of the varieties used in the cold storage investigations of the Department of Agriculture are printed in black type, with their leading synonyms in italics.]

Aiken Red. (See Akin.)

Akin. Synonym: *Aiken Red.*

W. S. Miller, Gerrardstown, Berkeley County, W. Va.: Highly colored, No. 1; picked October 12, 1901, stored October 18; sound and in good commercial condition until March 11, 1902, after which it decayed.

Albemarle. (See Yellow Newtown.)

Alexander.

M. Reeks, Douglas, Allegan County, Mich.: Large, well colored, No. 1; picked August 25, 1902, stored August 27; at commercial limit November 14, 1902.

Amos. Synonym: *Amos Jackson.*

New York State Experiment Station, Geneva, Ontario County, N. Y.: Small, hard, and green; picked September 19, 1902, stored September 27; May 1, 1903, firm, no scald or rot.

Amos Jackson. (See Amos.)

Apple of Commerce. (See Beach.)

Arctic.

Maine Agricultural Experiment Station, Orono, Penobscot County, Me.: Well colored, No. 1; picked October 7, 1902, stored October 24; January 23, 1903, in good commercial condition, scald beginning to appear; March 11, softening, color faded, all scalded.

Arkansas. Synonyms: *Blacktwig, Mammoth Blacktwig.*

W. S. Miller, Gerrardstown, Berkeley County, W. Va.: Hard, No. 1; picked October 12, 1901, stored October 18; May 1, 1902, bright, firm, and sound, no rot or scald.

Ozark Orchard Company, Goodman, McDonald County, Mo.: No. 2 stock; badly affected with "flyspeck" fungus; picked October 11, 1902, stored October 28; March 10, 1903, shriveled, considerable rot, no scald.

Virginia Agricultural Experiment Station, Blacksburg, Montgomery County, Va.: Small, sound; picked September 26, 1901, stored October 6; May 1, 1902, firm, no decay, nearly all slightly scalded on light side.

Arkansas Beauty.

W. S. Miller, Gerrardstown, Berkeley County, W. Va.: Medium size, dull greenish red; picked October 7, 1901, stored October 18; January 23, 1902, 10 per cent of decay, no scald.

Arkansas Black.

Near Kansas Experiment Station, Manhattan, Riley County, Kans.: Small, very hard, poorly colored, immature stock; picked October 5, 1901, stored October 9; March 21, 1902, very hard, with no deterioration; would probably have kept well through storage season.

W. S. Miller, Gerrardstown, Berkeley County, W. Va.; Dark red, very fine, large; picked November 5, 1901, stored November 12; June 1, 1902, in prime commercial condition, hard, no scald or decay, except from injury.

Aucuba. Synonym: *Aucuba-Leaved Reinette.*

New York State Experiment Station, Geneva, Ontario County, N. Y.: Bright, well colored, No. 1; picked October 12, 1901, stored October 21; sound and in good condition until February 1, 1902.

Aucuba-Leaved Reinette. (See Aucuba.)

Bailey Sweet.

G. T. Powell, Ghent, Columbia County, N. Y.: Bright, No. 1; picked October 16, 1902, stored October 20; in prime condition until March 1, 1903, when the fruit began to mellow; no scald or decay. Identity uncertain.

Baker.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Hard, greenish, No. 1; picked September 22, 1902, stored September 29; firm and sound until March 14, 1903, after which it softened.

Baldwin.

F. L. Bradley, Barker, Niagara County, N. Y.: Mixed grade, dull, scabby; picked October 9, 1902, stored October 15; May 1, 1903, firm, no scald or rot.

J. E. Brown, Wilson, Niagara County, N. Y.: No. 1, fair color; picked October 8, 1901, stored October 15; May 1, 1902, firm, no rot, slight scald.

H. M. Dunlap, Southern Illinois: Firm, somewhat wormy; picked October 8, 1901, stored October 10; March 18, 1902, commencing to scald and decay.

Z. A. Gilbert, Farmington, Franklin County, Me.: Medium sized, dull colored; date of picking undetermined, stored November 10, 1902; May 1, 1903, firm, no decay or scald.

G. G. Hitchings, South Onondaga, Onondaga County, N. Y.: Large, dark red, No. 1; trees 12 years old; picked October 1, 1902, stored October 4; May 1, 1903, firm, no scald or rot.

W. T. Mann, Barker, Niagara County, N. Y.: Hard, finely colored, No. 1; picked October 16, 1902, stored October 18; May 1, 1903, hard, no scald or rot.

Massachusetts Agricultural College Experiment Station, Amherst, Hampshire County, Mass.: Dull greenish red, No. 1; picked October 11, 1902, stored October 15; May 1, 1903, no scald or rot, hard.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Hard, light colored, small; picked October 12, 1902, stored October 15; May 1, 1903, hard and sound; similar in 1901.

G. T. Powell, Ghent, Columbia County, N. Y.: Bright, well colored, No. 1; picked October 16, 1902, stored October 19; May 1, 1903, firm condition, no scald or decay.

Virginia Experiment Station, Blacksburg, Montgomery County, Va.: Firm, light colored, No. 1; picked September 26, 1901, stored October 6; May 1, 1902, semi-firm, no scald or decay; kept unusually well for a northern variety and was of much better grade and color than most of the other sorts from same source.

Beach. Synonyms: *Apple of Commerce, Richardson's Red.*

W. S. Miller, Gerrardstown, Berkeley County, W. Va.: Bright, sound, No. 1; picked November 5, 1902, stored November 12; May 1, 1903, sound and in prime commercial condition.

Beauty of Kent. (See KENT BEAUTY.)

Bellflower. (See YELLOW BELLFLOWER.)

Ben Davis.

G. J. Dodd, Greenwood, Jackson County, Mo.: Hard, well colored, No. 1; picked October 1, 1902, stored October 4; March 10, 1903, in good market condition; scald and rot slight.

H. M. Dunlap, Southern Illinois: No. 1 stock; picked October 8, 1901, stored October 10; March 18, 1902, in fair market condition; somewhat injured by scald and decay.

G. G. Hitchings, South Onondaga, Onondaga County, N. Y.: Hard, medium sized, highly colored; trees 12 years old; picked October 22, 1901, stored October 26; May 1, 1902, firm and sound, no scald.

S. L. Lupton, Winchester, Frederick County, Va.: Firm, light colored, wormy; picked October 4, 1901, stored October 12; March 27, 1902, considerable scald, decay slight.

Ben Davis—Continued.

Massachusetts Agricultural College Experiment Station, Amherst, Hampshire County, Mass.: Small and hard; picked October 13, 1902, stored October 15; May 1, 1903, firm and sound.

W. S. Miller, Gerrardstown, Berkeley County, W. Va.: Firm, well colored, No. 1; picked October 2, 1901, stored October 18; May 1, 1902, firm, no rot or scald.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Small, hard, light colored; date of picking undetermined, stored November 12, 1902; May 1, 1903, semifirm, no scald or decay; similar in 1902.

Ozark Orchard Company, Goodman, McDonald County, Mo.: Medium to very large, well colored; picked October 10, 1902, stored October 28; March 10, 1903, overripe, slightly wilted, considerable decay.

F. H. Speakman, Neosho, Newton County, Mo.: Sound, well colored, No. 1; picked October 24, 1901, stored October 28; March 20, 1902, in good market condition, slight rot and scald.

G. E. Spohr, Manhattan, Riley County, Kans.: Small, poorly colored; picked October 11, 1901, stored October 18; March 20, 1902, badly shriveled, no decay or scald; received through Kansas Experiment Station.

Virginia Agricultural Experiment Station, Blacksburg, Montgomery County, Va.: Small, well colored, somewhat wormy; picked September 26, 1901, stored October 8; May 1, 1902, semifirm, no scald, decay slight.

Black Gilliflower. Synonym: *Gilliflower.*

G. G. Hitchings, South Onondaga, Onondaga County, N. Y.: Light colored, No. 1; trees about 100 years old; picked October 1, 1902, stored October 4; May 1, 1903, in prime commercial condition; similar for fruit picked in 1901.

Massachusetts Agricultural College Experiment Station, Amherst, Hampshire County, Mass.: Dull colored, No. 2; picked October 10, 1902, stored October 15; firm until January 1, 1903; decayed badly after February 1.

G. T. Powell, Ghent, Columbia County, N. Y.: Well colored, No. 1; picked October 16, 1902, stored October 19; February 1, 1903, badly injured by rot.

Black Oxford.

Z. A. Gilbert, Farmington, Franklin County, Me.: Hard, dull colored, No. 1; date of picking undetermined, stored November 10, 1902; May 1, 1903, firm, no scald or rot.

Blacktwig. (See Arkansas and Paragon.)

Bonum.

A. A. Boggs, Waynesville, Haywood County, N. C.: Bright, dark red, No. 1; picked September 15, 1902, stored September 26; May 1, 1903, firm, no rot or scald.

Borsdorf.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Small, light colored; picked September 19, 1902, stored September 27; March 14, 1903, soft, badly decayed.

Buckingham.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Small, hard, and immature; picked September 25, 1902, stored September 27; May 1, 1903, firm, no decay, scalds slight; commercial limit April 1.

Buler. Synonym: *Jonathan of Buler.*

New York Experiment Station, Geneva, Ontario County, N. Y.: Light red, No. 1; picked September 20, 1902, stored September 27; commercial limit February 1, 1903, after which fruit scalded badly, but remained firm till April 1.

Canada Red. (See Red Canada.)

Canada Reinette.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Hard, dull colored; picked October 12, 1901, stored October 19; May 1, 1902, mellow, no decay, scald slight; best commercial limit April 1.

Cannon Pearmain.

W. S. Miller, Gerrardstown, Berkeley County, W. Va.: Well colored, No. 1; picked October 12, 1901, stored October 18; May 1, 1902, in prime commercial condition, no scald or decay; a long keeper.

Virginia Agricultural Experiment Station, Blacksburg, Montgomery County, Va.: Hard, cloudy, somewhat wormy; picked October 3, 1901, stored October 5; May 1, 1902, firm, decay slight, no scald; commercial limit April 1.

Carlough.

W. S. Miller, Gerrardstown, Berkeley County, W. Va.: Hard, sound, No. 1; picked October 12, 1901, stored October 18; May 1, 1902, firm, no rot or scald; a long keeper.

Carthouse. (See GILPIN.)

Cayuga Redstreak. (See TWENTY OUNCE.)

Clarke.

New York State Experiment Station, Geneva, Ontario County, N. Y.: No. 1; picked October 12, 1901, stored October 21; February 1, 1902, mellow, no scald, decay slight; commercial limit December 1; flesh grows soft and mealy and discolors at end of commercial life.

Coffelt. Synonym: *Coffelt Beauty.*

W. S. Miller, Gerrardstown, Berkeley County, W. Va.: Hard, well colored, No. 1; picked October 11, 1901, stored October 18; May 1, 1902, firm, no scald or decay; a long keeper.

Coffelt Beauty. (See COFFELT.)

Cogswell.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Small, hard, and immature; picked October 3, 1902, stored October 11; May 1, 1903, firm, no scald or decay.

Colvert.

G. G. Hitchings, South Onondaga, Onondaga County, N. Y.: No. 1, picked October 1, 1902, stored October 4; firm until January 15, 1903.

Coon Red.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Small and immature; picked September 23, 1902, stored September 28; May 1, 1903, semi-firm, no decay, scald slight; commercial limit March 15.

Cooper Market.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Light colored, No. 1; picked October 12, 1901, stored October 21; May 1, 1902, hard and sound.

Crawford. Synonym: *Crawford Pippin.*

W. S. Miller, Gerrardstown, Berkeley County, W. Va.: Hard, well colored, No. 1; picked October 11, 1901, stored October 18; March 11, 1902, commencing to scald; May 1, 1902, firm, no decay, nearly all light-colored specimens scalded.

Crawford Pippin. (See CRAWFORD.)

Crotts.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Hard and green; picked October 12, 1901, stored October 21; March 14, 1902, firm, no decay, badly scalded.

Cullen. Synonym: *Cullen's Keeper.*

Kansas Agricultural Experiment Station, Manhattan, Riley County, Kans.: Hard and green; picked October 7, 1901, stored October 10; May 1, 1902, firm, no scald or rot.

Cullen's Keeper. (See CULLEN.)

Deacon Jones.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Large, hard, bright, No. 1; picked October 4, 1902, stored October 11; May 1, 1903, mellow, free from scald and rot; commercial limit for barrel storage about March 1.

Delaware Red Winter. (See LAWVER.)

Dickenson.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Bright, No. 1; picked September 19, 1902, stored September 27; May 1, 1903; overripe and badly decayed; commercial limit February 1; commercial limit in 1901–2, March 1.

Disharoon.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Sound, No. 1; picked September 19, 1902, stored September 27; April 1, 1903, sound, but commencing to turn mellow, no scald or decay.

Doctor. Synonym: *Newby.*

Maine Agricultural Experiment Station, Orono, Penobscot County, Me.: Bright, clean, No. 1; picked October 7, 1901, stored October 10; May 1, 1902, firm, no scald, decay slight; commercial limit April 1 to 15.

Downing's Winter Maiden Blush. (See GREENVILLE.)

Duchess. (See OLDENBURG.)

Duchess of Oldenburg. (See OLDENBURG.)

Edwards.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Hard, green; picked October 12, 1901, stored October 21; May 1, 1902, hard and green, no scald or rot; sound, No. 1; picked September 20, 1902, stored September 27; March 14, 1903, quite mellow, no scald or rot.

Elgin Pippin. (See ELGIN.)

Esopus. Synonyms: *Esopus Spitzenburg; Spitzenburg.*

F. L. Bradley, Barker, Niagara County, N. Y.: Scabby and poorly colored; picked September 27, 1902, stored October 3; firm until March 1, 1903, when the fruit commenced to decay around scab spots.

G. G. Hitchings, South Onondaga, Onondaga County, N. Y.: Dark red, No. 1; trees about 100 years old; picked October 1, 1902, stored October 4; May 1, 1903, firm, no scald or decay.

New York State Experiment Station, Geneva, Ontario County, N. Y.: No. 1; picked October 21, 1902, stored October 27; May 1, 1903, semifirm, no decay or scald; in barrels should be sold April 1.

G. T. Powell, Ghent, Columbia County, N. Y.: Well colored, No. 1; picked October 16, 1902, stored October 19; in prime commercial condition until April 1, 1903, after which the fruit began to mellow; no rot.

The flesh of this variety becomes mealy when overripe.

Esopus Spitzenburg. (See ESOPUS.)

Ewalt.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Well colored, No. 1; picked October 6, 1902, stored October 11; March 14, 1903, beginning to mellow, decay slight, no scald; commercial limit in barrels February 1.

Excelsior.

Michigan Agricultural College Experiment Substation, South Haven, Van Buren County, Mich.: Light colored, No. 1; picked September 8, 1902, stored September 10; November 14, 1902, overripe, quality gone.

Fallawater.

G. G. Hitchings, South Onondaga, Onondaga County, N. Y.: Large, finely colored, No. 1; trees 12 years old; picked October 1, 1901, stored October 12; March 1, 1902, beginning to mellow; May 1, 1902, quite mellow but free from decay and scald; commercial limit February 1.

New York State Experiment Station, Geneva, Ontario County, N. Y.: No. 1, but very green; picked October 12, 1901, stored October 21; May 1, 1902, semifirm, no decay or scald; held in good semifirm condition for box storage from March 1 to May 1.

Fall Pippin.

Massachusetts Agricultural College Experiment Station, Amherst, Hampshire County, Mass.: Large, bright, No. 1; picked September 30, 1902, stored October 3; in firm condition until January 1, 1903, when the fruit began to mellow.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Bright, No. 1; picked September 24, 1902, stored September 29; January 27, 1903, commencing to soften. Fruit picked in 1901 kept in good condition until January 10, 1902; may be held in boxes till February 1.

Fall Queen. (See HAAS.)

Fameuse. Synonym: *Snow.*

G. G. Hitchings, South Onondaga, Onondaga County, N. Y.: Well colored, No. 1; trees 12 years old; picked October 7, 1902, stored October 12; in good commercial condition until March 15, 1903. Fruit picked in 1901 kept in good condition until February 15, 1902.

Maine Agricultural Experiment Station, Orono, Penobscot County, Me.: Slight colored, No. 1; ripe and somewhat bruised; picked October 7, 1902, stored October 24; January 23, 1903, in good condition for box storage, no scald or decay; March 11, overripe and past commercial condition.

Massachusetts Agricultural College Experiment Station, Amherst, Hampshire County, Mass.: Bright, No. 1; picked September 30, 1902, stored October 3; February 15, firm, no scald or rot; commercial limit about March 1.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Hard, bright, No. 1; picked October 12, 1901, stored October 21; January 31, 1902, mellow, no decay or scald; March 14, very ripe but still sound.

Geo. T. Powell, Ghent, Columbia County, N. Y.: Bright, dark red, No. 1; picked October 13, 1902, stored October 19; February 1, 1903, in prime commercial condition; March 1, mellow, free from scald and decay.

This variety reaches its commercial limit usually between January 1 and March 1.

Fanny.

Michigan Agricultural College Experiment Substation, South Haven, Van Buren County, Mich.: No. 1, highly colored; picked September 2, 1902, stored September 3; firm, sound, and beautifully colored November 14, 1902; would probably have held in good condition several weeks longer.

Fishkill.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Large, sound, well colored; picked October 4, 1901, stored October 11; began to decay internally, while still firm outside, after January 1–15, 1902; behavior similar in 1902–3.

Gano.

New York Experiment Station, Geneva, Ontario County, N. Y.: Small, hard, half colored; picked September 27, 1902, stored October 1; May 1, 1903, semifirm, some rot; commercial limit April 1.

Ozark Orchard Company, Goodman, McDonald County, Mo.: Very large, highly colored; picked October 6, 1902, stored October 11; March 11, 1903, overripe, 18 per cent decay; behavior similar in 1901–2; commercial limit February 1.

G. E. Spohr, Manhattan, Riley County, Kans.: Fruit large, well colored, firmer than Ozark Orchard stock; picked October 1, 1901, stored October 6; March 20, 1902, firm, no decay or scald; would probably have kept well a month longer; received through Kansas Experiment Station.

Virginia Agricultural Experiment Station, Blacksburg, Montgomery County, Va.: Well colored, firm, medium grade, considerable codling-moth injury; picked September 26, 1901, stored October 16; February 1, 1902, firm, with no decay or scald, after which the decay proceeded quite rapidly.

Geniton. (See RALLS.)

Gibb.

W. S. Miller, Gerrardstown, Berkeley County, W. Va.: Hard, No. 1; picked October 2, 1901, stored October 18; May 1, 1902, in prime commercial condition, no scald or decay; a long keeper.

Gideon.

Michigan Agricultural College Experiment Substation, South Haven, Van Buren County, Mich.: Hard, light colored, rather immature; picked September 9, 1902, stored September 10, 1902; November 14, 1902, firm, sound; commercial limit probably January 1.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Bright, No. 1; picked October 12, 1901, stored October 21, 1901; commercial limit January 1, 1902; after that the flesh began to discolor at the core, a characteristic of this variety after it reaches maturity.

Gilliflower. (See BLACK GILLIFLOWER.)

Gilpin. Synonym: *Carthouse.*

G. G. Hitchings, South Onondaga, Onondaga County, N. Y.: Medium sized, bright, half colored, very hard; trees 28 years old; picked after October 1, 1901; stored October 12, 1901; began to scald March 15, 1902, and scalded badly, but remained hard through storage season; behavior similar in 1902–3, except scalding began a month later.

Gold Medal. Synonym: *Golden Medal.*

New York State Experiment Station, Geneva, Ontario County, N. Y.: Hard, green, good; picked October 3, 1901, stored October 11; commercial limit February 1 to 15, 1902, after which the fruit softened; no scald.

Golden Medal. (See GOLD MEDAL.)

Golden Russet (N. Y.).

Maine Agricultural Experiment Station, Orono, Penobscot County, Me.: Bright, hard, well russeted, No. 1; picked October 7, 1901, stored October 24, 1901; commercial limit May 1, 1902, when stock was hard, but mellowing began soon after.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Hard, greenish russet, No. 1; picked October 24, 1902, stored November 15; May 1, 1903, prime commercial condition, no decay; similar in 1901–2, but by June 1 the fruit was mellow and decay was setting in.

Gravenstein.

Michigan Agricultural College Experiment Substation, South Haven, Van Buren County, Mich.: No. 1, quite well colored; picked September 9, 1902, stored September 11; November 14, 1902, ripe, but still firm, quality good; should be sold by November 1.

New York State Experiment Station, Geneva, Ontario County, N. Y.: No. 1, highly colored; picked September 18, stored September 27, 1902; commercial limit December 1, 1902, after which it softened; no scald.

Green Crimean.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Hard, sound; picked October 4, 1902, stored October 11; May 1, 1903, firm, in good commercial condition; no scald or decay.

Green Newtown. Synonym: *Newtown Pippin.*

New York State Experiment Station, Geneva, Ontario County, N. Y.: No. 1; picked October 12, 1901, stored October 21; in March, 1902, it was too green for use; May 1 hard, no decay, scald slight.

Green Sweet.

W. S. Miller, Gerrardstown, Berkeley County, W. Va.: No. 1; picking date undetermined; stored October 18, 1901; commercial limit March 1 to 15, 1902, when it began to mellow; no scald.

Greening. (See RHODE ISLAND.)

Greenville. Synonym: *Downing's Winter Maiden Blush.*

New York State Experiment Station, Geneva, Ontario County, N. Y.: Large, finely colored, No. 1; picked October 12, 1901, stored October 21, 1901; in excellent commercial condition till February 1, 1902, when scald began to develop; one-third scalded March 14, 1902.

Grimes. Synonym: *Grimes Golden.*

W. S. Miller, Gerrardstown, Berkeley County, W. Va.: Bright, No. 1; picked September 20, 1901, stored October 16; mellow when stored; began to deteriorate from decay after January 1, 1902.

New York State Experiment Station, Geneva, Ontario County, N. Y.: No. 1, fair color; picked October 2, 1902, stored October 11; in good condition commercially till February 1, 1903, when scald began to develop; May 1, all scalded, semifirm.

Virginia Agricultural Experiment Station, Blacksburg, Montgomery County, Va.: No. 2; considerable codling-moth injury; picked September 26, 1901, stored October 16; limit December 1, 1901, after which the fruit rotted badly; scald began to develop in March, 1902; probably injured by delay in storage.

Grimes Golden. (See GRIMES.)

Haas. Synonym: *Fall Queen.*

Maine Agricultural Experiment Station, Orono, Penobscot County, Me.: Well colored, No. 1; picked September 16, 1901, stored October 24; semifirm when stored; commercial limit December 1, 1901, after which the flesh began to soften throughout.

Massachusetts Agricultural College Experiment Station, Amherst, Hampshire County, Mass.: Mixed grade, well colored; picked September 3, 1902; stored October 3; firm till December 1, 1902, after which the flesh became mealy; no scald.

New York State Experiment Station, Geneva, Ontario, County, N. Y.: Fair colored, No. 1; picked September 7, 1902, stored September 27; after December 1, 1902, the flesh began to mellow, grow mealy, and decay.

Haskell.

New York State Experiment Station, Geneva, Ontario County, N. Y.: No. 1; picked October 1 to 12, 1901, stored October 21; commercial limit January 15, 1902, after which the fruit began to soften; no scald.

Haskell Sweet. (See HASKELL.)

Henniker. Synonym: *Lady Henniker.*

New York State Experiment Station, Geneva, Ontario County, N. Y.: Well colored, No. 1; picked September 9, 1902, stored September 27; after December 1, 1902, the flesh began to mellow; no scald.

Highfill. Synonym: *Hyfill.*

Ozark Orchard Company, Goodman, McDonald County, Mo.: Large, No. 1; highly colored; picked October 20, 1902, stored October 28; March 10, 1903, semifirm, slightly shriveled, one-third decayed; no scald; commercial limit probably January 15.

Holland. Synonym: *Holland Pippin.*

G. G. Hitchings, South Onondaga, Onondaga County, N. Y.: Large, bright, No. 1; picked September 1, 1902, stored September 29; after December 1, 1902, the flesh began to soften; no scald.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Large, well colored, No. 1; picked October 12, 1901, stored October 21; after February 1, 1902, the fruit began to soften; no scald till long after its commercial season.

Holland Pippin. (See HOLLAND.)

Hubbardston. Synonyms: *Hubbardston Nonesuch, Nonesuch.*

Z. A. Gilbert, Farmington, Franklin County, Me.: Medium size, well colored, mixed grade; picking date undetermined, stored November 10, 1902; after December 1, 1902, the flesh softened throughout; probably ripe when stored.

G. G. Hitchings, South Onondaga, Onondaga County, N. Y.: Large, finely colored, considerable codling-moth injury; trees six years old; picked October 5, 1902, stored October 12; prime commercial condition till February 1, 1903, when it began to shrivel; April 1, soft.

Kansas Agricultural Experiment Station, Manhattan, Riley County, Kans.: Medium to small, pale greenish red; picked October 8, 1901, stored October 12; no softening and but little decay till April 1, 1902; fruit began to wilt after February 1, 1902.

Massachusetts Agricultural College Experiment Station, Amherst, Hampshire County, Mass.: Medium size, rather dull color; picked September 30, 1902, stored October 3; good commercial condition for barrel storage till January 15, 1903; for box storage till February 15, 1903, after which the fruit mellowed and became mealy.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Small, hard, immature; picked October 4, 1902, stored October 11; prime condition May 1, 1903.

G. T. Powell, Ghent, Columbia County, N. Y.: Very large, overgrown, highly colored; picked October 4, 1902, stored October 9; firm till December 1, 1902, after which the flesh grew mealy; January 15, 1903, all burst.

The flesh of this variety usually becomes mealy when it passes maturity

Hubbardston Nonesuch. (See HUBBARDSTON.)

Huntsman. Synonym: *Huntsman Favorite.*

G. J. Dodd, Greenwood, Jackson County, Mo.: Well-colored, No. 1; picked October 1, 1902, stored October 4; March 10, 1903, all scalded slightly, but very firm; commercial limit, February 1, 1903.

Huntsman—Continued.

H. M. Dunlap, Southern Illinois: Well-colored, No. 1; picked October 8, 1901, stored October 10; prime commercial condition till February 1, 1902, after which scald appeared.

W. S. Miller, Gerrardstown, Berkeley County, W. Va.: Highly colored, No. 1; picked October 9, 1901, stored October 18; in prime commercial condition June 1, 1902, hard, bright yellow; no scald or decay.

Huntsman Favorite. (See Huntsman.)

Hurlbut.

Maine Agricultural Experiment Station, Orono, Penobscot County, Me.: Bright, well-colored, No. 1; picked October 7, 1901, stored October 24; good condition till February 1, 1902, when scald and decay began to develop; semifirm when stored.

Massachusetts Agricultural College Experiment Station, Amherst, Hampshire County, Mass.: Medium sized, fair color; picked September 20, 1902, stored October 3, 1902; firm till February 15, 1903; no scald or rot; would probably have kept well a month longer in boxes.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Hard, not well colored; picked September 12, 1902, stored September 27; firm till April 1, 1903, after which the flesh softened.

Hyfill. (See Highfill.)

Ingram.

W. T. Flournoy, Marionville, Lawrence County, Mo.: Hard, well-colored, No. 1; picked October 10, 1902, stored October 18; March 10, 1903, in prime commercial condition, firm, free from scald and rot; would have kept a number of weeks longer.

Ivanhoe.

W. S. Miller, Gerrardstown, Berkeley County, W. Va.: Well-colored, No. 1; picked November 5, 1901, stored November 12; prime commercial condition till June 1, 1902, when wilting began; no scald or rot.

Virginia Agricultural Experiment Station, Blacksburg, Montgomery County, Va.: Hard, fair grade, considerable "flyspeck" fungus and codling-moth injury; picked September 30, 1901, stored October 16; no rot or scald throughout storage season, but fruit wilted so as to injure its commercial value after February 1, 1902.

Jacobs. Synonym: *Jacobs Sweet.*

New York State Experiment Station, Geneva, Ontario County, N. Y.: Green, No. 1; picked September 9, 1901, stored September 27; firm till March 1, 1902, good condition for box storage till April 1; no scald. The crop of 1902 began to mellow February 1, but it held in good condition for box storage till April 1.

W. S. Miller, Gerrardstown, Berkeley County, W. Va.: Large, clear, No. 1; picked October 11, 1901, stored October 18; in prime condition till April 1, 1902, after which the fruit softened.

Jacobs Sweet. (See Jacobs.)

Jefferis.

Michigan Agricultural College Experiment Substation, South Haven, Van Buren County, Mich.: Well-colored, No. 1; picked September 2, 1902; stored September 3; November 14, 1902, bright in appearance, but quality poor; commercial limit probably October 15.

Johnson's Fine Winter. (See York Imperial.)

Jonathan.

G. J. Dodd, Greenwood, Jackson County, Mo.: Large, well colored, firm, No. 1; picked September 22, 1902, stored September 24; commercial limit probably February 1, 1903; March 11, 1903, 20 per cent decayed.

Jonathan—Continued.

G. G. Hitchings, South Onondaga, Onondaga County, N. Y.: Dark red, bright, No. 1; trees 6 years old; picked October 5, 1901, stored October 12; in prime condition for barrel storage till April 1, 1902; in good condition for box storage till June 1, 1902; no rot; held well for a long time after the fruit began to mellow.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Small, hard, considerably russeted; picked October 23, 1902, stored October 27; May 1, 1903, hard, no rot, in prime commercial condition.

G. T. Powell, Ghent, Columbia County, N. Y.: Medium sized, highly colored; picked October 16, 1902, stored October 19; in prime condition for barrel storage till March 1, 1903, when it began to mellow; good condition for box storage till May 1; no rot or scald.

F. H. Speakman, Neosho, Newton County, Mo.: Large, highly colored, No. 1; picked September 25, 1901, stored October 16; commercial limit about February 1, 1902; when inspected March 20 the fruit was mellow, with considerable decay; probably injured by delayed storage.

G. E. Spohr, Manhattan, Riley County, Kans.: Well colored, No. 1; picked October 1, 1901, stored October 12; prime till February 1, 1902, when the fruit began to mellow; received through Kansas Experiment Station.

Jonathan of Buler. (See Buler.)

Jones Seedling.

W. S. Miller, Gerrardstown, Berkeley County, W. Va.: Clear colored, No. 1; picked November 5, 1901, stored November 12; good commercial condition till March 1, 1902, when scald developed; firm throughout storage season.

Kansas.

W. S. Miller, Gerrardstown, Berkeley County, W. Va.: Highly colored, No. 1; picked October 8, 1901, stored October 18; in prime commercial condition throughout storage season; no rot or scald.

Kansas Keeper.

New York Experiment Station, Geneva, Ontario County, N. Y.: Very hard, immature; picked October 2, 1901, stored October 21; hard, with no scald or decay June 1, 1902.

Kent Beauty. Synonym: *Beauty of Kent.*

Massachusetts Agricultural College Experiment Station, Amherst, Hampshire County, Mass.: Large, well colored, No. 1; picked September 30, 1902, stored October 31; kept well till January 1, 1903, after which the flesh softened and became mealy; no scald.

King. (See Tompkins King.)

Kirtland.

New York State Experiment Station, Geneva. Ontario County, N. Y.: Dark red, No. 1; picked October 12, 1901, stored October 21; prime commercial condition throughout the storage season; no scald or decay.

Lady Henniker. (See Henniker.)

Lady Sweet.

G. G. Hitchings, South Onondaga, Onondaga County, N. Y.: Bright, clear, medium sized, three-fourths red, No. 1; picked October 1, 1902, stored October 4; May 1, 1903, prime commercial condition, firm, no rot or scald.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Hard, half-green, immature; picked October 21, 1902, stored October 27; hard and sound through storage season.

G. T. Powell, Ghent, Columbia County, N. Y.: Fancy large, bright red, from young trees; picked October 16, 1902, stored October 19; prime condition for barrel storage till March 15, 1903, when fruit began to mellow; good condition for box storage till May 1; no scald or decay.

Lankford.

S. H. Derby, Woodside, Kent County, Del.: Large, well colored No. 1; picked September 29, 1902, stored October 30; began to scald January 15, 1903, and firm till March 1.

W. S. Miller, Gerrardstown, Berkeley County, W. Va.: Bright, No. 1, well colored; picked October 12, 1901, stored October 18; began scalding January 15, 1902, but remained hard, with no decay, till June 1.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Medium sized, very hard, half colored; picked October 12, 1901, stored October 21; began scalding in January, 1902, but remained hard through storage season.

Virginia Agricultural Experiment Station, Blacksburg, Montgomery County, Va.: Medium grade, considerable injury from codling moth and "flyspeck" fungus; picked September 26, 1901, stored October 16; began scalding April 1, 1902; semifirm after February 1, 1902.

This apple is usually one of the worst scalding varieties after midwinter.

Lansberger Reinette.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Bright, No. 1; picked October 12, 1901, stored October 21; commercial limit January 15, 1902, after which the flesh mellowed; no scald.

Lawver. Synonym: *Delaware Red Winter.*

Near Kansas Agricultural Experiment Station, Manhattan, Riley County, Kans.: No. 1, rather dull red; picked October 21, 1901, stored October 18; good commercial condition March 20, 1902, and apparently would have kept well throughout storage season; received through Kansas Experiment Station.

Massachusetts Agricultural College Experiment Station, Amherst, Hampshire County, Mass.: Small, dull red, very hard; picked October 11, 1902, stored October 15; May 1, 1903, hard, no scald or decay.

W. S. Miller, Gerrardstown, Berkeley County, W. Va.: Large, bright, dark red; picked October 11, 1901, stored October 16; good commercial condition till March 15, 1902, when some of the apples began to grow mealy; ripened unevenly; fruit overgrown.

Virginia Agricultural Experiment Station, Blacksburg, Montgomery County, Va.: Small, No. 2; considerably injured by codling moth; picked September 27, 1901, stored October 16; May 1, 1902, hard and in good condition; a few decayed from bruising.

Leicester.

Massachusetts Agricultural College Experiment Station, Amherst, Hampshire County, Mass.: Large, dull yellow, with blush; picked September 30, 1902, stored October 3; after January 1, 1903, the flesh became mealy; no scald.

Limbertwig.

Near Kansas Agricultural Experiment Station, Manhattan, Riley County, Kans.: Small, greenish-red, immature; picked October 15, 1901, stored October 10; very hard throughout storage season; no rot or scald; fruit received through Kansas Agricultural Experiment Station.

Longfield.

Maine Agricultural Experiment Station, Orono, Penobscot County, Me.: Clear, No. 1; mellow when stored; picked September 16, 1901, stored October 24; at end of commercial season when stored.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Clear, well colored, No. 1; picked October 12, 1901, stored October 21, semifirm when stored; commercial limit December 1, 1901, after which the flesh grew mealy.

Lowell.

New York State Experiment Station, Geneva, Ontario County, N. Y.: No. 1; picked September 2, 1902, stored September 3; commercial limit October 15, 1902, after which it softened and lost quality.

Loy.

Kansas Agricultural Experiment Station, Manhattan, Riley County, Kans.: Pale, greenish-red, grade No. 1; picked October 4, 1901, stored October 9; March 10, 1902, considerably wilting, no scald, decay slight; commercial limit March 1, 1902.

W. S. Miller, Gerrardstown, Berkeley County, W. Va.: Well colored, No. 1; picked October 9, 1901, stored October 18; May 1, 1902, prime commercial condition, firm, no rot or scald.

McIntosh. Synonym: *McIntosh Red.*

G. G. Hitchings, South Onondaga, Onondaga County, N. Y.: Well colored, No. 1; trees 12 years old; picked October 7, 1901, stored October 12; firm till January 15, 1902, after which it became mellow; behavior similar in 1902–1903.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Well colored, No. 1; picked October 12, 1901, stored October 21; firm till January 15, 1902; good condition for box storage till March 1, 1902; in 1902–1903 the fruit was firm a month longer.

McIntosh Red. (See McIntosh.)

McMahon. Synonym: *McMahon White.*

New York State Experiment Station, Geneva, Ontario County, N. Y.: No. 1; unevenly colored; picked October 12, 1901, stored October 21; commercial limit December 1, 1901; ripens unevenly.

McMahon White. (See McMahon.)

Magog.

New York State Experiment Station, Geneva, Ontario County, N. Y.: No. 1; picked September 18, 1902, stored September 27; commercial limit January 15, 1902, after which the flesh softened; no scald.

Maiden Blush.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Well colored, No. 1; picked October 12, 1901, stored October 21; after December 15, 1901, the flesh softened; behavior similar in 1902; no scald.

Mammoth Blacktwig. (See Arkansas.)

Manchester.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Small, immature, very hard; picked September 20, 1902, stored September 27; May 1, 1903, hard, immature; no scald or rot.

Mann.

W. T. Mann, Barker, Niagara County, N. Y.: Large, bright, clear, No. 1; soil sandy; picked October 24, 1902, stored October 25; May 1, 1903, yellowish, bright, hard; no rot or scald; from clay soil, greener and less attractive at end of storage season.

Massachusetts Agricultural College Experiment Station, Amherst, Hampshire County, Mass.: Medium size, grassy green, dull; picked October 11, 1902, stored October 15; May 1, 1903, very hard and green; no rot or scald.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Small, hard, grassy green; picked October 3, 1902, stored October 11; May 1, 1903, hard and green; no rot or scald.

Manwaring.

New York State Experiment Station, Geneva, Ontario County, N. Y.: No. 1; picked September 27, 1902, stored October 1; commercial limit January 15, 1903, after which it decayed badly.

Marigold.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Immature, small; picked October 6, 1902, stored October 11; May 1, 1903, very hard; no decay, scald slight.

Marmalade.

Michigan Agricultural College Experiment Substation, South Haven, Van Buren County, Mich.: No. 1; picked August 22, 1902, stored September 3; probably semifirm when stored; November 14, 1902, semifirm; quality poor; no rot.

Melon. Synonym: *Norton's Melon.*

New York State Experiment Station, Geneva, Ontario County, N. Y.: Hard, green; picked October 12, 1901, stored October 21; May 1, 1902, still hard and green; no scald or rot; in 1902–1903 the fruit softened after February 1 and decayed considerably.

Milden. Synonym: *Milding.*

Z. A. Gilbert, Farmington, Franklin County, Me.: Medium size, well colored, No. 1: picking date undetermined, stored November 10, 1902; firm till March 1, 1903; in good condition for box storage till May 1, 1903; no scald, slight decay from bruising.

Maine Agricultural Experiment Station, Orono, Penobscot County, Me.: Large, bright No 1; picked October 7, 1901, stored October 24, semifirm at storing time: held semifirm and in good condition for storage in boxes till May 1, 1902, after which it softened and decayed.

Milding. (See MILDEN.)

Milligen.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Firm, No. 1; picked October 6, 1902, stored October 11; after January 15, 1903, scald appeared, though the fruit was firm with slight scald till March 15.

Minkler.

H. M. Dunlap, Southern Illinois: No. 1; picked October 4. 1901, stored October 10; good commercial condition till February, 1902; March 17 nearly one-fourth scalded, but fruit firm; considerable decay.

Missouri. Synonym: *Missouri Pippin.*

F. H. Speakman, Neosho, Newton County, Mo.: Large, highly colored, No. 1; picked October 20, 1901, stored October 30; March 20, 1902, prime commercial condition, hard, no scald or decay; behavior similar in 1903; commercial limit probably April 15 to May 1.

Virginia Agricultural Experiment Station, Blacksburg, Montgomery County, Va.: No. 2, scabby, considerable "flyspeck" fungus and codling-moth injury; picked September 26, 1901, stored October 16; firm till March 1, 1902, after which the fruit decayed badly.

Missouri Pippin. (See MISSOURI.)

Monmouth.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Bright, green, No. 1; picked October 12, 1901, stored October 21; May 1, 1902, in prime commercial condition; firm, no rot or scald; behavior similar in 1902–1903; commercial limit about June 1.

Moore Sweet.

New York State Experiment Station, Geneva, Ontario County, N. Y.: No. 1, immature; picked October 12, 1901, stored October 21; firm, with no decay or scald till April 15, 1902, after which it softened.

Mother.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Firm, poorly colored, No. 1; picked September 17, 1902, stored September 27, firm till March 15; semifirm and in good condition for storage in boxes till May 1, 1903; no decay or scald.

Munson. Synonym: *Munson Sweet.*

Maine Agricultural Experiment Station, Orono, Penobscot County, Me.. Clear yellow, No. 1; ripe when stored; picked September 16, 1901, stored October 24; the fruit, though semifirm, held in good condition with no rot or scald till February 5, 1902, after which it softened.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Fair colored, No. 1; picked September 25, 1902, stored September 29; in good condition till January 1, 1903, after which it softened; no scald or decay.

Munson Sweet. (See MUNSON.)

Nansemond. Synonym: *Nansemond Beauty.*

Virginia Agricultural Experiment Station, Blacksburg, Montgomery County, Va.: No. 2, small, light in color, injured by codling moth; picked September 24, 1901, stored October 16; in good condition till February 1, 1902, after which both decay and scald appeared.

Nansemond Beauty. (See NANSEMOND.)

Nero.

W. S. Miller, Gerrardstown, Berkeley County, W. Va.: Large, not well colored, immature, picked September 27, 1901, stored October 18; semifirm when stored, in good condition till March 1, 1902, after which the fruit softened and scald appeared. The delay in storing undoubtedly shortened its storage period.

Virginia Agricultural Experiment Station, Blacksburg, Montgomery County, Va.: No. 2, badly affected with codling moth, well colored; picked September 26, 1901, stored October 16; after February 1 the fruit decayed considerably, though still firm; scald appeared March 1, 1902.

This variety is inclined to scald considerably after midwinter, unless it is highly colored.

Neverfail. (See RALLS GENET.)

Newby. (See DOCTOR.)

Newman.

New York State Experiment Station, Geneva, Ontario County, N. Y.: No. 1; picked October 12, 1901, stored October 21; May 1, 1902, firm, in prime commercial condition; no decay or scald.

Newtown Pippin. (See GREEN NEWTOWN and YELLOW NEWTOWN.)

Newtown Spitzenburg.

G. G. Hitchings, South Onondaga, Onondaga County, N. Y.: Large, highly colored, No. 1; trees 100 years old; picked October 5, 1901, stored October 8; in good condition for barrel storage till March 15; semifirm and in good condition for storage in boxes till April 15, 1902; no scald or rot.

G. T. Powell, Ghent, Columbia County, N. Y.: Medium sized, bright, light colored, No. 1; picked October 13, 1902, stored October 19; in good condition for barrel storage till February 15, when the fruit began to mellow; good condition for box storage till March 15, 1903, after which the flesh became mealy, and later the fruit burst; no scald or decay.

New Water.

New York State Experiment Station, Geneva, Ontario County, N. Y.. No 1; picked October 12, 1901, stored October 21; firm till January 15, 1902; in good condition till March 1; no decay or scald.

Nonesuch. (See HUBBARDSTON.)

Northern Spy.

F. L. Bradley, Barker, Niagara County, N. Y.: Poor grade, light colored; picked October 9, 1902, stored October 15; May 1, 1903, firm and in good condition; no rot or scald.

A. A. Boggs, Waynesboro, Haywood County, N. C.: Large, dark red, fancy; picked September 25, 1902, stored September 30; firm until December 1, 1902, after which it decayed and softened rapidly.

G. G. Hitchings, South Onondaga, Onondaga County, N. Y.: Large, highly colored, fancy; trees 6 years old; picked October 22, 1901, stored October 26; May 1, 1902, prime commercial condition, firm, no scald, slight rot.

New York State Experiment Station, Geneva, Ontario, County, N. Y.: Well colored, No. 1; picked October 12, 1901, stored October 21; May 1, 1902, firm, good commercial condition. Picked November 3, 1902, stored November 15; light colored; in good condition till March 1, 1903, after which the fruit decayed considerably.

G. T. Powell, Ghent, Columbia County, N. Y.: Fancy, medium size, dark red; picked October 16, 1902, stored October 19; May 1, 1903, hard, no rot or decay, and in prime condition.

This variety is variable in its storage behavior. It is particularly susceptible to decay from blue mold, especially if bruised or delayed in reaching storage. If well colored, picked, packed, and handled with great care, and stored soon after picking, it may be carried in storage as long as most winter varieties.

Northwestern Greening.

W. S. Miller, Gerrardstown, Berkeley County, W. Va.: Well colored, No. 1; picked October 11, 1901, stored October 18; May 1, 1902, hard, no scald or decay, in prime commercial condition.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Medium size, No. 1; picked October 12, 1901, stored October 21; May 1, 1902, hard, no scald or decay; good commercial condition till June 1, 1902, when it began to soften.

Norton's Melon. Synonym of Melon.

Oakland. Synonym: *Oakland Seeknofurther.*

New York State Experiment Station, Geneva, Ontario County, N. Y.: Bright, hard, No. 1; picked October 12, 1901, stored October 21; firm till March 1, 1902; semifirm, in good condition for box storage till April 15; no decay or scald.

Oakland Seeknofurther. (See OAKLAND.)

Oldenburg. Synonym: *Duchess of Oldenburg.*

J. F. Taylor, Douglas, Allegan County, Mich.: Hard, light colored, No. 1; picked August 20, 1902, stored August 21; November 14, 1902, in prime market condition, less than 1 per cent of rot, no shrinkage; commercial limit probably about December 15.

Oliver. Synonym: *Senator.*

W. S. Miller, Gerrardstown, Berkeley County, W. Va.: No. 1; picked November 4, 1901, stored November 12, semifirm when stored; May 1, 1902, semifirm, decay slight, no scald; commercial limit probably late in spring when stored firm.

Ontario.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Hard, green, No. 1; picked October 2, 1902, stored October 11; March 14, 1903, firm, no decay or scald; May 1, soft and worthless.

Ornament. Synonym: *Ornament de Table.*

New York State Experiment Station, Geneva, Ontario County, N. Y.: Small, light colored; picked September 22, 1902, stored September 27; May 1, 1903, firm, decay slight, no scald. Fruit picked in 1901 in similar condition May 1, 1902.

Ornament de Table. (See ORNAMENT.)

Palmer Greening. (See WASHINGTON ROYAL.)

Paragon. Synonym: *Blacktwig.*

New York State Experiment Station, Geneva, Ontario County, N. Y.: Hard, green, No. 1; picked October 12, 1901, stored October 21; March 14, 1902, firm, but badly scalded; May 1, nearly all scalded, firm, no decay.

Peck Pleasant.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Hard and green; picked October 4, 1902, stored October 11; May 1, 1903, firm, no decay, scald slight.

Virginia Agricultural Experiment Station, Blacksburg, Montgomery County, Va.: No. 1, somewhat cloudy and wormy; picked September 26, 1901, stored October 6; January 24, 1902, semifirm, no scald or decay; May 1, past best commercial condition, considerable rot; commercial limit March 1.

Peter.

Michigan Agricultural College Experiment Substation, South Haven, Van Buren County, Mich.: Hard, well colored, No. 1; picked September 9, 1902, stored September 10; November 14, 1902, in prime market condition, firm and sound; commercial limit probably January 1.

Pewaukee.

G. G. Hitchings, South Onondaga, Onondaga County, N. Y.: Well colored, No. 1; trees 12 years old, picked September 25, 1902, stored September 29; May 1, 1903, firm, no rot or scald. Fruit picked in 1901 kept in similar condition.

Maine Agricultural Experiment Station, Orono, Penobscot County, Me.: Well colored, No. 1; picked October 7, 1902, stored October 24; May 1, 1903, firm, decay slight, no scald.

Massachusetts Agricultural College Experiment Station, Amherst, Hampshire County, Mass.: Well colored, No. 1; picked October 8, 1902, stored October 12; May 1, 1903, firm, no scald or decay.

W. S. Miller, Gerrardstown, Berkeley County, W. Va.: Well colored, No. 1; picked October 8, 1901, stored October 18; May 1, 1902, no scald or rot, firm.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Small, hard, and undercolored; picked October 4, 1902, stored October 11; May 1, 1903, hard and green, no rot; fruit picked in 1901 kept in similar condition.

Phoenix.

G. G. Hitchings, South Onondaga, Onondaga County, N. Y.: Poor, scabby, light red; picked October 1, 1902, stored October 4; May 1, 1903, hard, no scald or rot. Identity uncertain.

Piper.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Hard, green, No. 1; picked October 12, 1901, stored October 21; May 1, 1902, hard, no scald or decay.

Pound Sweet. (See PUMPKIN SWEET.)

Pride of Texas. (See TEXAS.)

Pryor. Synonym: *Pryor Red.*

W. S. Miller, Gerrardstown, Berkeley County, W. Va.: Hard, No. 1; picked October 11, 1901, stored October 18; May 1, 1902, firm, free from rot and scald.

Pryor Red. (See PRYOR.)

Pumpkin Russet.

New York State Experiment Station, Geneva, Ontario County, N. Y.: No. 1; picked September 17, 1902; stored September 27; January 6, 1903, a little past commercial condition, commencing to soften.

Pumpkin Sweet. Synonyms: *Pound Sweet; Lyman's Pumpkin Sweet.*

G. G. Hitchings, South Onondaga, Onondaga County, N. Y.: Large, well colored, but many water-cored; trees 10 years old; picked October 1, 1902, stored October 4; in good condition until January 15, 1903, when the fruit began to soften and decay; fruit picked in 1901 kept in similar condition.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Medium sized, hard, and green; picked October 2, 1902, stored October 11; May 1, 1903, firm, decay slight, no scald; received as Pumpkin Sweet.

George T. Powell, Ghent, Columbia County, N. Y.: Large, No. 1; picked October 6, 1902, stored October 9; in good commercial condition until January 1, 1903, when the fruit began to decay.

This variety often discolors in flesh after it reaches a ripe condition, but the texture remains firm after the discoloration takes place.

Quince *Cole.*

Michigan Agricultural College Experiment Substation, South Haven, Van Buren County, Mich.: Sound, No. 1; picked September 2, 1902, stored September 3; November 14, 1902, semifirm, quality somewhat impaired, no decay or scald; commercial limit November 1.

Ralls. Synonyms: *Geniton; Ralls Genet; Neverfail.*

H. M. Dunlap, Southern Illinois: Small, imperfect, No. 2; picked October 9, 1901, stored October 15; January 17, 1902, firm, no decay or scald; March 18, considerable decay and some scald.

W. S. Miller, Gerrardstown, Berkeley County, W. Va.: Bright, clean, No. 1; picked October 12, 1901, stored October 18; May 1, 1902, in prime condition, no rot, or decay.

Ralls Genet. (See RALLS.)

Rambo.

H. M. Dunlap, Southern Illinois: Well colored, No. 1; picked October 9, 1901, stored October 15; January 17, 1902, quite ripe, but free from decay and scald; March 18, overripe and commencing to soften.

G. G. Hitchings, South Onondaga, Onondaga County, N. Y.: Well colored, No. 1; trees about 100 years old; picked October 1, 1902, stored October 6; in prime commercial condition until April 1, 1903, when the fruit began to soften. Fruit picked in 1901 kept in similar condition.

Red Canada. Synonyms: *Canada Red; Steele's Red Winter.*

G. G. Hitchings, South Onondaga, Onondaga County, N. Y.: Dark red, No. 1; trees 6 years old; dates of picking and storing undetermined; in prime commercial condition until April 15, 1902, after which date the fruit softened very quickly.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Immature, hard, No. 1; picked October 12, 1901, stored October 21; May 1, 1902, firm, free from scald and decay.

Red Russet.

Massachusetts Agricultural College Experiment Station, Amherst, Hampshire County, Mass.: Dull colored, wormy, No. 2; picked October 13, 1902, stored October 15; May 1, 1903, firm, no scald or decay.

Red Winter Sweet.

George T. Powell, Ghent, Columbia County, N. Y.: Bright, No. 1; picked October 13, 1902, stored October 19; March 1, 1903, quite mellow, no scald or decay.

Reinette Pippin.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Hard, immature, No. 1; picked October 1, 1902, stored October 11; March 14, 1903, firm, no scald, decay slight; May 1, semifirm, quality good, considerable decay. Fruit picked in 1901 reached its commercial limit February 1, 1902, and by March 14 was badly scalded and specked with rot.

Rhode Island.

F. L. Bradley, Barker, Niagara County, N. Y.: Firm, poorly graded; picked September 27, 1902, stored October 3; in commercial condition until March 15, 1903; May 1, injured by scald and decay.

J. E. Brown, Wilson, Niagara County, N. Y.: Not closely graded; many small and wormy fruits; dates of picking and storing undetermined; March 13, 1902, considerable scald, decay slight.

G. G. Hitchings, South Onondaga, Onondaga County, N. Y.: Bright, dark green, No. 1; picked October 7, 1901, stored October 12; in prime commercial condition until March 15, 1902, when the fruit began to scald, May 1, firm but badly scalded. Fruit picked in 1902 kept in similar condition.

Z. A. Gilbert, Farmington, Franklin County, Me.: Small, green, fair, No. 1; picking date undetermined, stored November 14, 1902; May 1, 1903, in good commercial condition, free from scald and decay.

W. T. Mann, Barker, Niagara County, N. Y.: Bright, large, No. 1; from heavy soil, very green; from sandy soil, larger and yellower; picked October 11, 1902, stored October 13; May 1, 1903, in prime commercial condition, no scald or decay.

Massachusetts Agricultural College Experiment Station, Amherst, Hampshire County, Mass.: Dull green, No. 2, covered with "flyspeck" fungus; picked October 8, 1902, stored October 12; in commercial condition until February 1, 1903, when the fruit began to mellow and grow mealy, while very green outside.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Hard, sound, No. 1; picked October 3, 1902, stored October 11; in good commercial condition until March 15, 1903, when the fruit began to discolor and soften. Fruit picked in 1901 kept in similar condition until the middle of March, 1902, except for the appearance of considerable scald.

George T. Powell, Ghent, Columbia County, N. Y.: Bright, well colored, No. 1; picked October 5, 1902, stored October 9, in good commercial condition until May 1, 1903, when the scald began to appear.

Rhode Island Greening. (See Rhode Island.)

Rhodes.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Poorly colored, No. 1; picked October 1 to 12, 1901, stored October 25; in prime condition till April 1, 1902, after which it became mellow; in good condition for box storage till May 1; no scald; picked September 22, 1902, stored September 27; mellow by January 15, 1903.

Rhodes Orange. (See Rhodes.)

Richardson's Red. (See Beach.)

Rome.

A. A. Boggs, Waynesville, Haywood County, N. C.: Large, dark red, No. 1; picked September 15, 1902, stored September 26; March 1, 1903, firm, no scald or rot.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Hard, light colored, No. 1; picked November 5, 1902, stored November 15; March 14, 1903, firm and sound. Fruit picked in 1901 in good commercial condition until May 1, 1902.

Rome—Continued.

G. E. Spohr, Manhattan, Riley County, Kans.: Small, poorly colored; dates of picking and storing undetermined; March 20, 1902, considerably shriveled, but free from rot and scald.

Rome Beauty. (See Rome.)

Roxbury.

F. L. Bradley, Barker, Niagara County, N. Y.: Sound, No. 1; picked October 1, 1902, stored October 3; in good commercial condition until May 1, 1903, aside from slight shriveling.

J. E. Brown, Wilson, Niagara County, N. Y.: No. 1; dates of picking and storing undetermined; May 1, 1902, in prime commercial condition, no shriveling, free from rot.

Massachusetts Agricultural College Experiment Station, Amherst, Hampshire County, Mass.: Medium sized, green, not well russeted; picked October 13, 1902, stored October 15; May 1, 1903, in good commercial condition, no rot, some wilting.

W. S. Miller, Gerrardstown, Berkeley County, W. Va.: No. 1; picked November 4, 1901, stored November 12; May 1, 1902, in prime commercial condition, no wilting, free from rot.

New York State Experiment Station, Geneva, Ontario County, N. Y.: No. 1; picked October 24, 1902, stored November 15; May 1, 1903, firm, no decay. Fruit picked in 1901 kept in similar condition.

George T. Powell, Ghent, Columbia County, N. Y.: Large, bright, No. 1; picked October 16, 1902, stored October 19; in prime commercial condition until May 1, 1903.

Virginia Agricultural Experiment Station, Blacksburg, Montgomery County, Va.; Bright, No. 1; picked September 26, 1901, stored October; May 1, 1902, in prime commercial condition, no wilting or decay.

Roxbury Russet. (See Roxbury.)

Salome.

W. S. Miller, Gerrardstown, Berkeley County, W. Va.: Large, bright, highly colored, No. 1; picked October 9, 1901, stored October 18; semifirm January 1, 1902, but held in prime condition till May 1, when scald appeared and the fruit mellowed.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Hard, medium sized, light colored; picked October 12, 1902, stored October 21; in good condition till April 1, 1903, when scald appeared freely; June 1, still hard, but all scalded.

Scarlet Cranberry.

Massachusetts Agricultural Experiment Station, Amherst, Hampshire County, Mass.: Medium to small, very hard, dull colored; picked October 13, 1902, stored October 15; May 1, 1903, hard, no scald or rot; would probably have kept much longer.

W. S. Miller, Gerrardstown, Berkeley County, W. Va.: Large, bright, well colored, No. 1; picked October 12, 1901, stored October 18; May 1, 1902, hard, bright, no scald or decay; would probably have kept much longer.

Scott Winter. Synonym: *Scott's Red Winter.*

New York State Experiment Station, Geneva, Ontario County, N. Y.: No. 1; picked October 12, 1901, stored October 21; May 1, 1902, sound, firm, but slightly wilted; no scald.

Scott's Red Winter. (See Scott Winter.)

Seeknofurther. (See Westfield.)

Senator. (See OLIVER.)

Sharp.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Small, hard, immature; picked October 12, 1901, stored October 21; firm till January 15, 1902; semifirm till March 15, after which scald appeared and the fruit softened.

Shiawassee. Synonym: *Shiawassee Beauty.*

Massachusetts Agricultural College Experiment Station, Amherst, Hampshire County, Mass.: Well colored, fair grade; picked October 13, 1902, stored October 15; firm till December 1, 1902, after which it softened and later burst open.

Shiawassee Beauty. (See SHIAWASSEE.)

Smith. Synonym: *Smith Cider.*

A. A. Boggs, Waynesville, Haywood County, N. C.: Large, bright, light colored, No. 1; picked September 25, 1902, stored September 30; firm till December 1, 1902, after which it softened and decayed badly.

H. M. Dunlap, Southern Illinois: Well colored, medium sized, No. 1; picked September 9, 1901, stored September 15; December 1, 1902, semifirm; in good box condition till February 1, 1902, after which scald appeared.

G. E. Spohr, Manhattan, Riley County, Kans.: Light colored, No. 1; picked October 3, 1901, stored October 12; in good commercial condition till February 15, 1902, after which scald appeared and the fruit mellowed.

Smith Cider. (See SMITH.)

Snow. (See FAMEUSE.)

Spitzenburg. (See ESOPUS.)

Spohr.

G. E. Spohr, Manhattan, Riley County, Kans.: Well colored, No. 1; picked October 3, 1901, stored October 12: hard and in prime commercial condition March 20, 1902, and apparently would have kept well throughout storage season; no rot or scald. The fruit received under this name appears to be Missouri Pippin.

Springdale.

W. S. Miller, Gerrardstown, Berkeley County, W. Va.: Large, well colored, No. 1; picked November 5, 1901, stored November 12; hard and in prime condition throughout storage season; removed from storage June 14, 1902, still hard and of bright color, no rot or scald; a long keeper.

Stanard.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Highly colored, No. 1; picked October 12, 1901, stored October 21; good commercial barrel condition till April 1; semifirm and in good box condition till May 1, 1902; no scald or rot; picked September 19, 1902, stored September 27; mellow after March 1, 1903.

Stark.

Maine Agricultural Experiment Station, Orono, Penobscot County, Me.: Large, well colored, bright, No. 1; picked October 7, 1901, stored October 14; in prime commercial condition June 14, 1902, when removed from storage; no scald or decay.

W. S. Miller, Gerrardstown, Berkeley County, W. Va.: Medium sized, hard, fair colored, No. 1; picked October 2, 1901, stored October 8; scald appeared after April 1, 1902, but fruit remained hard throughout storage season.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Hard, greenish red, No. 1; picked October 12, 1901, stored October 21; hard with no scald or decay June 6, 1902, when removed from storage.

Stayman. (See STAYMAN WINESAP.)

Stayman Winesap. Synonym: *Stayman.*

A. A. Boggs, Waynesville, Haywood County, N. C.: Fancy, dark red, bright, large, No. 1; picked October 25, 1902, stored November 26; overripe from delay on entering storage; 25 per cent decayed January 1, 1903; no scald.

S. H. Derby, Woodside, Kent County, Del.: Well colored, considerable injury from codling moth; picked September 29, 1902, stored October 1; May 1, 1903, in prime commercial condition, firm, no scald or rot.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Medium sized, rather dull colored, No. 1; picked October 1 to 12, 1901, stored October 21; in good condition till April 1, 1902, when the fruit began to scald; May 1, 65 per cent scalded, balance of fruit still hard.

Steele's Red Winter. (See RED CANADA.)

Strode. Synonym: *Strode's Birmingham.*

New York State Experiment Station, Geneva, Ontario County, N. Y.: Small, greenish yellow; picked September 20, 1902, stored September 27; in good condition till December 15, 1902, after which the skin cracked open, while the fruit was still firm.

Strode's Birmingham. (See STRODE.)

Stuart Golden.

W. S. Miller, Gerrardstown, Berkeley County, W. Va.: Bright, hard, No. 1; picked October 11, 1901, stored October 18; in prime commercial condition, hard, bright, no scald or rot, June 14, 1902, when taken from storage.

Sutton. Synonym: *Sutton Beauty.*

Massachusetts Agricultural College Experiment Station, Amherst, Hampshire County, Mass.: Medium sized, bright, dark red, No. 1; picked October 8, 1902, stored October 12; firm for barrel storage till February 1, 1903; semifirm and in good condition for box storage till March 15, 1903, after which the fruit became mellow; no scald or rot.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Medium sized, well colored, but rather dull, No. 1; picked October 21, 1902, stored October 27; firm for barrel storage till March 15, 1903; in good condition for box storage till April 15, 1903.

George T. Powell, Ghent, Columbia County, N. Y.: Fancy, large, bright, dark red, from young trees; picked October 6, 1902, stored October 9; firm for barrel storage till February 1, 1903; semifirm and in good condition for box storage till March 1, after which the flesh softened and became mealy; no rot or scald.

This variety does not keep as long as Baldwin from the same orchards.

Sutton Beauty. (See SUTTON.)

Swaar.

Near Kansas Agricultural College, Manhattan, Riley County, Kans.: Clean, No. 1; picked October 9, 1901, stored October 13; March 20, 1902, firm, no scald or rot.

Massachusetts Agricultural College Experiment Station, Amherst, Hampshire County, Mass.: Dull colored, fair, No. 1; picked October 8, 1902, stored October 12; May 1, 1903, firm, no rot or scald.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Hard, green, No. 1; picked October 12, 1901, stored October 21; May 1, 1902, firm, no decay, scald slight.

George T. Powell, Ghent, Columbia County, N. Y.: Bright, greenish yellow, No. 1; picked October 13, 1902, stored October 19; May 1, 1903, in prime market condition, no scald or rot.

Talman Sweet. (See TOLMAN.)

Texas. Synonym: *Pride of Texas.*

New York State Experiment Station, Geneva, Ontario County, N. Y.: Small, hard, and green; picked October 12, 1901, stored October 21; May 1, 1902, firm, no rot, considerable scald.

Titovka.

Michigan Agricultural College Experiment Substation, South Haven, Van Buren County, Mich.: Large, well colored, No. 1; picked August 21, 1902, stored September 3; September 16, 1902, fully ripe and highly colored; November 14, overripe; many fruits cracked open and flesh discolored.

Titus. Synonym: *Titus Pippin.*

New York State Experiment Station, Geneva, Ontario County, N. Y.: Hard, green, No. 1; picked October 6, 1902, stored October 11; May 1, 1903, firm, no decay or scald.

Titus Pippin. (See Titus.)

Tolman. Synonyms: *Tolman Sweet; Talman Sweet.*

F. L. Bradley, Barker, Niagara County, N. Y.: Fair, No. 1; picked October 9, 1902, stored October 15; May 1, 1903, firm, no decay or scald.

Z. A. Gilbert, Farmington, Franklin County, Me.: Fair, No. 1; picking date undetermined, stored November 14, 1902; May 1, 1903, hard, no decay or scald.

G. G. Hitchings, South Onondaga, Onondaga County, N. Y.: Bright, clear yellow, No. 1; trees 40 years old; picked October 1, 1902, stored October 4; May 1, 1903, firm, no decay or scald; fruit picked in 1901 kept in similar condition.

Massachusetts Agricultural College Experiment Station, Amherst, Hampshire County, Mass.: Bright, No. 1; picked September 30, 1902, stored October 3; began to mellow after March 1, 1903; no scald or rot.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Small, hard, No. 1; picked September 27, 1902, stored October 1; May 1, 1903, firm, no decay, scald slight.

Tolman Sweet. (See Tolman.)

Tompkins King. Synonym: *King.*

F. L. Bradley, Barker, Niagara County, N. Y.: Well colored, No. 1; picked October 9, 1902, stored October 15; in good commercial condition until April 15, 1903, after which the fruit became mellow.

J. E. Brown, Wilson, Niagara County, N. Y.: Well colored, No. 1, picked October 9, 1901, stored October 17; April 9, 1902, in good commercial condition, decay slight, no scald; commercial limit May 1.

G. G. Hitchings, South Onondaga, Onondaga County, N. Y.: Large, dark red, No. 1; trees 13 years old; picked October 5, 1901, stored October 12; May 1, 1902, firm, no scald or rot; fruit packed in 1902 did not keep later than April 1, 1903.

Massachusetts Agricultural College Experiment Station, Amherst, Hampshire County, Mass.: Medium sized, bright, half colored; picked September 30, 1902, stored October 3; May 1, 1903, firm, no rot or scald.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Small, hard, and green; picked September 23, 1902, stored September 27; May 1, 1903, green and hard, no decay or scald; fruit picked in 1901 kept in sound condition until May 1, 1902.

George T. Powell, Ghent, Columbia County, N. Y.: Very large, well colored, No. 1, from young, rank-growing trees; picked October 4, 1902, stored October 9; held well until January 1, 1903, when the fruit began to soften and become mealy.

Tufts. Synonym: *Tufts Baldwin.*

New York State Experiment Station, Geneva, Ontario County, N. Y.: Hard, greenish red, No. 1; picked September 16, 1902, stored September 27; March 14, 1903, firm and sound; May 1, softening, no rot, scald slight.

Tufts Baldwin. (See TUFTS.)

Twenty Ounce. Synonym: *Cayuga Redstreak.*

G. G. Hitchings, South Onondaga, Onondaga County, N. Y.: Large, well colored, No. 1; trees 12 years old; dates of picking and storing undetermined; January 15, 1902, ripe, but still firm and sound.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Well colored, No. 1; picked September 25, 1902, stored September 29; January 6, 1903, mellow, commencing to decay. Fruit picked in 1901 kept well until February 1, 1902.

Vanhoy.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Hard, green, fair, No. 1; picked October 12, 1901, stored October 21; May 1, 1902, firm, no rot, considerable scald.

Via.

Virginia Agricultural Experiment Station, Blacksburg, Montgomery County, Va.: Clean, No. 1; picked September 26, 1901, stored October 18; May 1, 1902, semi-firm, no decay or scald; good commercial condition for storage in boxes.

Victoria Sweet.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Well colored, No. 1; picked October 12, 1901, stored October 21; January 10, 1902, beautifully colored, quite mellow.

Wagener.

G. G. Hitchings, South Onondaga, Onondaga County, N. Y.: Fair, No. 1; picked October 1, 1902, stored October 4; began scalding February 1, 1903, and by March 15 over 50 per cent of the fruit was scalded; commercial limit about February 1 on account of scald.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Hard, well colored, No. 1; picked November 5, 1902, stored November 15; March 14, firm, no decay or scald; May 1, 1903, soft, considerable decay, no scald.

George T. Powell, Ghent, Columbia County, N. Y.: Half red, No. 1; picked October 16, 1902, stored October 19; held in prime condition until April 1, 1903; no rot or scald; after February 1 the light side of the fruit would scald badly within forty-eight hours after removal from storage.

This variety unless highly colored is one of the worst to scald after midwinter.

Walbridge.

G. G. Hitchings, South Onondaga, Onondaga County, N. Y.: Large, well colored, No. 1; picked October 7, 1902, stored October 12; in good commercial condition until February 1, 1903, when scald began to develop. Fruit picked in 1901 kept in similar condition. Commercial limit February 1 to 15.

Maine Agricultural Experiment Station, Orono, Penobscot County, Me.: Hard, medium sized, No. 1; picked October 7, 1901, stored October 24; March 11, 1902, firm, no scald or rot; commercial limit May 1, after which scald and decay appeared.

Massachusetts Agricultural College Experiment Station, Amherst, Hampshire County, Mass.: Hard, poorly colored, fair, No. 1; picked October 13, 1902, stored October 15; May 1, 1903, hard, no rot or scald.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Hard, green, fair, No. 1; picked October 12, 1901, stored October 21; after March 15, 1902, the fruit softened and much of it became mealy.

This variety often ripens unevenly and becomes mealy and discolored in flesh while the skin is bright in color

Washington Royal. Synonym: *Palmer Greening.*

Massachusetts Agricultural College Experiment Station, Amherst, Hampshire County: Bright, clear yellow, No. 1; picked October 8, 1902, stored October 12; in good commercial condition until January 1, 1903, when the fruit began to soften; in good condition for storage in boxes till February 1.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Small, hard, and green; picked October 3, 1902, stored October 11; April 30, 1903, mellow, no rot or scald; commercial limit March 1; fruit softens without developing yellow color.

Washington Strawberry.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Light colored, No. 1; picked October 12, 1901, stored October 21; January 10, 1902, mellow, no scald or rot; commercial limit December 1, 1901.

Wealthy.

G. G. Hitchings, South Onondaga, Onondaga County, N. Y.: Large, dark red, No. 1; picked September 20, 1902, stored September 24; in prime commercial condition until January 1, 1903, after which it began to soften and fade in color. Fruit picked in 1901 kept in similar condition.

E. Hutchins, Fennville, Allegan County, Mich.: Light colored, No. 1; picked August 28, 1902, stored September 2; November 14, 1902, in prime commercial condition, free from rot and scald; would have kept well for a number of weeks longer.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Small, hard, and immature; picked September 18, 1902, stored September 27; March 14, 1903, semifirm, decay slight, no scald.

Western Beauty.

New York State Experiment Station, Geneva, Ontario County, N. Y.: No. 1; picked October 12, 1901, stored October 21; May 1, 1902, firm, no rot or scald.

Westfield. Synonym: *Seeknofurther.*

G. G. Hitchings, South Onondaga, Onondaga County, N. Y.: Large, well colored, No. 1; picked October 1, 1902, stored October 5; May 1, 1903, firm, no rot or scald. Fruit picked in 1901, not so well colored, kept in similar condition.

Massachusetts Agricultural College Experiment Station, Amherst, Hampshire County, Mass.: Large, greenish, No. 1; picked October 8, 1902, stored October 12; May 1, 1903, hard, no rot or scald.

George T. Powell, Ghent, Columbia County, N. Y.: Medium sized, half colored; picked October 6, 1902, stored October 9; May 1, 1903, firm, no rot or scald.

White Doctor.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Small, greenish yellow; picked September 20, 1902, stored September 27; March 14, 1903, semifirm, decay slight, all scalded slightly. Fruit picked in 1901 kept in similar condition. Commercial limit February 1.

White Pippin.

A. A. Boggs, Waynesville, Haywood County, N. C.: Bright, large, No. 1; picked September 18, 1902, stored September 25; May 1, 1903, firm, no rot, scald light on a few; commercial limit April 15.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Sound, No. 1; picked October 6, 1902, stored October 11; March 14, 1903, firm, no scald; commercial limit April 15; fruit picked in 1901 after March 1, 1902, softened rapidly and decayed.

White Pearmain. Synonym: *White Winter Pearmain.*

Near Kansas Agricultural College, Manhattan, Riley County, Kans.: Small, immature; picked October 16, 1901, stored October 19; May 1, 1902, hard, no rot or scald.

White Winter Pearmain. (See WHITE PEARMAIN.)

Willow. Synonym: *Willowtwig.*

H M. Dunlap, Savoy, Ill.: No. 1; picked October 10, 1901, stored October 15; March 18, 1902, firm, slightly injured by scald and rot.

Virginia Agricultural Experiment Station, Blacksburg, Montgomery County, Va.: No. 2; cloudy and wormy; picked September 20, 1901; date of storing undetermined; May 1, 1902, commencing to shrivel, no scald, decay slight.

Willowtwig. (See WILLOW.)

Winesap.

S. H. Derby, Woodside, Kent County, Del.: Hard, light red, No. 1; picked September 29, 1902, stored September 31; May 1, 1903, hard, no scald or rot; in prime condition to carry for many weeks.

G. J. Dodd, Greenwood, Jackson County, Mo.: Well colored, No. 1; picked October 1, 1901, stored October 4; March 10, 1903, in prime commercial condition, no rot, scald very slight; commercial limit, on account of scald, March 15.

H. M. Dunlap, Savoy, Champaign County, Ill.: No. 1; slightly wormy; picked October 23, 1901, stored October 28; January 17, 1902, sound and in good commercial condition; March 18, firm, no scald, decay slight; fruit picked two weeks earlier and lighter in color was one-third scalded.

G. G. Hitchings, South Onondaga, Onondaga County, N. Y.: Small, hard, dark red; trees 6 years old; picked October 13, 1902, stored October 16; kept well until March 1, 1903, when scald began to develop. Fruit picked in 1901 kept in similar condition. Hard throughout storage season.

Near Kansas Agricultural College, Manhattan, Riley County, Kans.: Hard, small, poorly colored; picked October 4, 1901, stored October 10; March 20, 1902, hard, no rot or scald; commercial limit probably April 15.

S. L. Lupton, Winchester, Frederick County, Va.: Fair, No. 1; color fair; somewhat cloudy and wormy; picked October 18, 1901, stored October 22; March 27, 1902, firm, decay very slight, about one-third scalded.

Ozark Orchard Company, Goodman, McDonald County, Mo.: Well colored, No. 1; picked October 8, 1902, stored October 13; March 10, 1903, firm, no scald, 20 per cent of rot; commercial limit February 1.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Hard, small, light colored; picked October 12, 1901, stored October 21; March 14, 1902, firm, no decay or scald; April 30, about 75 per cent of scald, no decay, hard.

Virginia Agricultural Experiment Station, Blacksburg, Montgomery County, Va.: Medium sized, fair, No. 1; picked September 30, 1901, stored October 17; May 1, 1902, firm, no scald, very slight decay, and wilting.

Winter Maiden Blush. (See GREENVILLE.)

Winter Paradise. Synonym: *Winter Sweet Paradise.*

W. S. Miller, Gerrardstown, Berkeley County, W. Va.: No. 1; dates of picking and storing undetermined; May 27, 1902, in prime commercial condition, no rot or scald.

Winter Streifling.

Michigan Agricultural College Experiment Substation, South Haven, Van Buren County, Mich.: Light colored, No. 1; picked September 1, 1902, stored September 3; November 14, 1902, hard and sound; would have kept a number of weeks longer.

Winter Sweet Paradise. (See WINTER PARADISE.)

Wolf River.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Large, bright, No. 1; picked September 25, 1902, stored September 27; January 6, 1903, in prime commercial condition, no rot or scald.

Yellow Bellflower. Synonym: *Bellflower.*

F. I Bradley, Barker, Niagara County, N. Y.: No. 2 grade, scabby and russeted; picked October 9, 1902, stored October 15; May 1, 1903, semifirm and free from scald and decay.

G. T. Powell, Ghent, Columbia County, N. Y.: Highly colored, No. 1; picked October 9, 1902, stored October 13; April 1, 1903, beginning to mellow, no scald or rot.

Yellow Newtown. Synonyms: *Albemarle; Newtown Pippin; Yellow Newtown Pippin.*

S. L. Lupton, Winchester, Frederick County, Va.: Medium sized, well colored, wormy; picked October 7, 1901, stored October 10; May 1, 1902, firm, decay and scald slight; commercial limit April 1.

W. S. Miller, Gerrardstown, Berkeley County, W. Va.: Bright, No. 1; picked October 10, 1901, stored October 18; June 14, 1902, in prime commercial condition, no scald or decay.

Virginia Agricultural Experiment Station, Blacksburg, Montgomery County, Va.: Somewhat wormy; picked September 27, 1901, stored October 17; June 14, 1902, firm, color and quality good; decay and scald slight; commercial limit May 15.

Yellow Newtown Pippin. (See YELLOW NEWTOWN.)

York Imperial. Synonym: *Johnson's Fine Winter.*

A. A. Boggs, Waynesville, Haywood County, N. C.: Hard, bright, half colored, No. 1; picked September 18, 1902, stored September 25; May 1, 1903, firm, no scald or decay.

S. L. Lupton, Winchester, Frederick County, Va.: Medium grade, greenish red, considerable codling moth; picked October 4, 1901, stored October 12; scalded badly after January 1, 1902; fruit picked October 23, dark red, began to scald after February 1, but did not scald as badly as the early picked fruit; the commercial limit of the dark fruit was six weeks longer.

New York State Experiment Station, Geneva, Ontario County, N. Y.: Medium to small, light colored, very hard; picked October 1-12, 1901, stored October 21; began to scald February 15, 1902, and a month later three-fourths of the fruit was lightly scalded on the green side; remained firm throughout season; commercial limit February 15 to March 15.

Ozark Orchard Company, Goodman, McDonald County, Mo.: Large, well colored, No. 1; picked October 8, 1902, stored October 13; March 10, 1903, overripe, somewhat shriveled, one-third of the fruit decayed, no scald; commercial limit January 15.

Virginia Agricultural Experiment Station, Blacksburg, Montgomery County, Va.: Bright, well colored, No. 1; picked September 26, 1901, stored October 17; January 24, 1902, firm, no decay, one-third of the fruit slightly scalded; commercial limit January 1.

F. Wellhouse, Tonganoxie, Leavenworth County, Kans.: Two-thirds colored; picked October 8, 1901, stored October 12; March 20, 1902, slightly wilted, some decay, one-fourth of the fruit scalded; commercial limit February 15.

York Stripe.

W. S. Miller, Gerrardstown, Berkeley County, W. Va.: Fair, No. 1; picked October 7, 1901, stored October 18; May 27, 1902, firm, slight decay, and scald; commercial limit May 1.

Zolotoreff.

Michigan Agricultural College Experiment Substation, South Haven, Van Buren County, Mich.: Large, well colored, No. 1; picked August 24, 1902, stored September 3; September 16, 1902, mellow, no rot or scald; November 14, appearance of fruit quite good, but flesh dry, discolored, and tasteless.

SUMMARY.

An apple usually should be fully grown and highly colored when picked, to give it the best keeping and commercial qualities. When harvested in that condition it is less liable to scald, of better quality, more attractive in appearance, and is worth more money than when it is picked in greener condition. (See pp. 16–18.)

An exception to the statement appears to exist in the case of certain varieties when borne on rapidly growing young trees. Such fruit is likely to be overgrown, and under these conditions the apples may need picking before they reach their highest color and full development. (See pp. 17, 23, 24.)

Uniform color may be secured by pruning to let the sunlight into the tree, by cultural conditions that check the growth of the tree early in the fall, and by picking over the trees several times, taking the apples in each picking that have attained the desired degree of color and size. (See pp. 18, 19.)

Apples should be stored as quickly as possible after picking. The fruit ripens rapidly after it is picked, especially if the weather is hot. The ripening which takes place between the time of picking and storage shortens the life of the fruit in the storage house. The fruit rots multiply rapidly if storage is delayed and the fruit becomes heated. If the weather is cool enough to prevent after-ripening, a delay in the storage of the fruit may not be injurious to its keeping quality. (See pp. 19, 21.)

A temperature of 31° to 32° F. retards the ripening processes more than a higher temperature. This temperature favors the fruit in other respects. (See pp. 21, 22.)

A fruit wrapper retards the ripening of the fruit; it preserves its bright color, checks transpiration and lessens wilting, protects the apple from bruising, and prevents the spread of fungous spores from decayed to perfect fruit. In commercial practice the use of the wrapper may be advisable on the finest grades of fruit that are placed on the market in small packages. (See pp. 22, 23.)

Apples that are to be stored for any length of time should be placed in closed packages. Fruit in ventilated packages is likely to be injured by wilting. Delicate fruit and fruit on which the ripening processes need to be quickly checked should be stored in the smallest practicable commercial package. The fruit cools more rapidly in small packages. (See pp. 24, 25.)

Apples should be in a firm condition when taken from storage, and kept in a low temperature after removal. A high temperature hastens decomposition and develops scald. (See pp. 25, 26.)

The best fruit keeps best in storage. When the crop is light it may pay to store fruit of inferior grade, but in this case the grades should be established when the fruit is picked. The bruising of the fruit leads to premature decay. (See p. 26.)

The scald is probably caused by a ferment or enzyme which works most rapidly in a high temperature. Fruit picked before it is mature is more susceptible than highly colored, well-developed fruit. (See pp. 26–28.)

After the fruit is picked its susceptibility to scald increases as the ripening progresses. (See pp. 28, 29.)

The ripening that takes place between the picking of the fruit and its storage makes it more susceptible to scald, and delay in storing the fruit in hot weather is particularly injurious. (See pp. 30, 31.)

The fruit scalds least in a low temperature. On removal from storage late in the season the scald develops quickly, especially when the temperature is high. (See pp. 29, 30.)

It does not appear practicable to treat the fruit with gases or other substances to prevent the scald. (See pp. 32, 33.)

From the practical standpoint the scald may be prevented to the greatest extent by producing highly colored, well-developed fruit, by storing it as soon as it is picked in a temperature of 31° to 32° F, by removing it from storage while it is still free from scald, and by holding it after removal in the coolest possible temperature. (See pp. 26–31.)

A variety may differ in its keeping quality when grown in different parts of the country. It may vary when grown in the same locality under different cultural conditions. The character of the soil, the age of the trees, the care of the orchard—all of these factors modify the growth of the tree and fruit and may affect the keeping quality of the apples. The character of the season also modifies the keeping power of the fruit. (See pp. 33–62.)

PLATES.

DESCRIPTION OF PLATES.

PLATE I. Frontispiece. Apple scald. The upper figure shows a light-colored York Imperial apple in March, 1903, with scald, which develops first and most severely on the least mature side of the fruit. The lower figure shows a highly colored York Imperial apple picked from the same tree at the time (October, 1902) when the upper specimen was picked. A trace of scald is shown on the right-hand side of the apple, where the color is not so dark as elsewhere.

Highly colored fruit is less susceptible to scald than fruit picked in an immature condition.

PLATE II. Tompkins King apples, February, 1903. This fruit was picked at two degrees of maturity in September, 1902, from young, rapidly growing trees. The upper specimen represents fruit that was highly colored but firm when picked; the lower figure shows fruit one-half to two-thirds colored. The less mature fruit kept in good condition a month longer than the highly colored apple. These apples were overgrown—a condition likely to occur on young trees.

From older trees, apples that are fully grown, highly colored, and firm when picked have kept as well in all cases (and better in many) than immature and undercolored fruit. The dark-colored York Imperial apples from older trees represented by the lower figure in Plate I, frontispiece, have longer-keeping qualities than the less mature fruit shown in the upper figure.

PLATE III. Methods of wrapping and packing apples. Fig. 1.—Apples unwrapped and in tissue, parchment, and wax wrappers, in order from left to right.

The wrapper retards the ripening of the fruit, preserves its bright color, checks transpiration, lessens wilting, protects the apple from bruising, and prevents the spread of fungous spores from decayed to perfect fruit.

Fig. 2.—Well packed barrel of Esopus *Spitzenburg* apples removed from storage in March, 1903. The fruit was properly packed in the orchard and repacking was not needed when the fruit was sold.

Fig. 3.—"Slack" packed barrel of Northern Spy apples removed from storage in March, 1903. The fruit was not packed firmly in the orchard. It settled in the barrel, leaving it "slack" when removed from storage. Barrels in this condition need to be repacked. The fruit is easily bruised and it deteriorates more quickly in the storage house and after removal when it is loosely packed.

PLATE IV. Baldwin apples from clay and from sandy soils, May 1, 1903. This fruit was picked in the same orchard in October, 1902, and was stored soon after picking at a temperature of 32° F. The fruit from the heavy clay soil represented by the upper figure was generally smaller and was much less highly colored. Both lots kept well throughout the storage season. The fruit from the sandy land represented in the lower figure was riper at the end of the storage season, better in quality, and worth more to the dealer and to the consumer.

PLATE V. Scald on Rhode Island *Greening* apple. The cross section shows that the scald is a surface trouble and does not extend into the flesh.

PLATE VI. Wagener apple. The upper figure represents the condition of the fruit when removed from storage in February, 1903, it having been picked in October, 1902, and stored at a temperature of 32° F. There was no scald on the apples when removed. Forty-eight hours later, after the fruit had been in a temperature of 70° F., the light-colored portion of the apples was badly scalded, as shown in the lower figure.

Late in the storage season the fruit is more susceptible to scald, and a high temperature when the fruit is removed from the storage house may develop it quickly.

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TOMPKINS KING APPLES. OVERGROWN ON YOUNG TREES.

FIG. 1.—APPLES UNWRAPPED AND IN TISSUE, PARCHMENT, AND WAX WRAPPERS.

FIG. 2.—WELL PACKED ESOPUS SPITZENBURG APPLES, REMOVED FROM STORAGE IN MARCH.

FIG. 3.—"SLACK" PACKED NORTHERN SPY APPLES, REMOVED FROM STORAGE IN MARCH.

METHODS OF WRAPPING AND PACKING APPLES.

BALDWIN APPLES.

UPPER FIGURE FROM CLAY SOIL; LOWER FIGURE FROM SANDY SOIL.

SCALD ON RHODE ISLAND GREENING APPLE.

WAGENER APPLE.

LOWER FIGURE, SCALD DEVELOPED AFTER REMOVAL FROM STORAGE HOUSE.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN No. 49.

B. T. GALLOWAY, Chief of Bureau.

THE CULTURE OF THE CENTRAL AMERICAN RUBBER TREE.

BY

O. F. COOK,

BOTANIST IN CHARGE OF INVESTIGATIONS IN TROPICAL AGRICULTURE.

BOTANICAL INVESTIGATIONS AND EXPERIMENTS.

ISSUED OCTOBER 1, 1903.

WASHINGTON:

GOVERNMENT PRINTING OFFICE.

1903.

BULLETINS OF THE BUREAU OF PLANT INDUSTRY.

The Bureau of Plant Industry, which was organized July 1, 1901, includes Vegetable Pathological and Physiological Investigations, Botanical Investigations and Experiments, Grass and Forage Plant Investigations, Pomological Investigations, and Experimental Gardens and Grounds, all of which were formerly separate Divisions, and also Seed and Plant Introduction and Distribution, the Arlington Experimental Farm, Tea Culture Investigations, and Domestic Sugar Investigations.

Beginning with the date of organization of the Bureau, the several series of bulletins of the various Divisions were discontinued, and all are now published as one series of the Bureau. A list of the bulletins issued in the present series follows.

Attention is directed to the fact that "the serial, scientific, and technical publications of the United States Department of Agriculture are not for general distribution. All copies not required for official use are by law turned over to the Superintendent of Documents, who is empowered to sell them at cost." All applications for such publications should, therefore, be made to the Superintendent of Documents, Union Building, Washington, D. C.

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16. A Preliminary Study of the Germination of the Spores of Agaricus Campestris and other Basidiomycetous Fungi. 1902. Price, 10 cents.
17. Some Diseases of the Cowpea. I. The Wilt Disease of the Cowpea and Its Control. II. A Cowpea Resistant to Root Knot (Heterodera radicicola). 1902. Price, 10 cents.

[Continued on page 3 of cover.]

PLANTED CASTILLA TREES ABOUT 14 YEARS OLD.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN No. 49.

B. T. GALLOWAY, Chief of Bureau.

THE CULTURE OF THE CENTRAL AMERICAN RUBBER TREE.

BY

O. F. COOK,

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1903.

BUREAU OF PLANT INDUSTRY.

B. T. Galloway, *Chief of Bureau.*

BOTANICAL INVESTIGATIONS AND EXPERIMENTS.

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LETTER OF TRANSMITTAL.

U. S. Department of Agriculture,
Bureau of Plant Industry,
Office of the Chief,
Washington, D. C., July 7, 1903.

Sir: I have the honor to transmit herewith, and to recommend for publication as Bulletin No. 49 of the series of this Bureau, the accompanying paper entitled "The Culture of the Central American Rubber Tree." It is especially opportune at this time that correct information should be disseminated on this subject, as interested parties have spread many delusive reports with a view to encouraging enterprises designed to exploit the rubber industry. Under these circumstances accurate and reliable information should be accessible to all classes of our citizens. This paper was prepared by Mr. O. F. Cook, Botanist in Charge of Investigations in Tropical Agriculture, and has been submitted by the Botanist with a view to publication.

The eighteen half-tone illustrations are considered necessary to a complete understanding of the text of this Bulletin.

Respectfully,

B. T. Galloway,
Chief of Bureau.

Hon. James Wilson,
Secretary of Agriculture.

PREFACE.

In the year 1902 the United States imported coffee to the value of $70,982,155, sugar[a] $55,061,097, and crude rubber $24,899,230. The imports of crude rubber for the last five years were valued as follows:

1898	$25,386,010
1899	31,707,630
1900	31,376,867
1901	28,455,383
1902	24,899,230
Total	141,825,120
Average	28,365,024

After sugar and coffee, crude rubber is the largest of the tropical imports of the United States, and it is the only one of these three for which we are still entirely dependent on foreign countries. Rubber culture is also the tropical industry in which the largest foreign investment of American capital has been made, and this is far larger than that of any other country.

The present paper on "The Culture of the Central American Rubber Tree" is the result of a preliminary study of rubber culture in Guatemala and Southern Mexico by Mr. O. F. Cook, Botanist in Charge of Investigations in Tropical Agriculture, who has already left for a second visit to Central America and Mexico, during which further attention will be devoted to the same subject.

These studies are directed primarily to the question whether rubber culture is promising for Porto Rico and the Philippines, and the principal fact established in this report, that a continuously humid climate is neither essential nor even desirable for rubber culture, promises well for the extension of this industry to the tropical islands of the United States. As a basis of effort in this direction the more important results of the experiments which have been made with the Para and other rubber trees in the East Indies and elsewhere have been brought together, with explanations of their possible bearing upon the culture of the Central American rubber tree.

The paper will have, however, a more immediate and popular interest in connection with the subject of investments in rubber culture,

[a] Not including imports from Hawaii and Porto Rico.

upon which this Department continues to receive a large amount of correspondence of a character which it has been very difficult to treat satisfactorily by letter.

A large proportion of the notes and illustrations used in the present paper were secured in the Soconusco district of Southern Mexico on the estate of the La Zacualpa Rubber Plantation Company, through whose hospitality and numerous courtesies the work of Mr. Cook was greatly facilitated.

FREDERICK V. COVILLE,
Botanist.

OFFICE OF BOTANICAL INVESTIGATIONS
AND EXPERIMENTS,
Washington, D. C., May 18, 1903.

CONTENTS.

ILLUSTRATIONS.

THE CULTURE OF THE CENTRAL AMERICAN RUBBER TREE.

INTRODUCTION.

Among the more striking results of the industrial progress of the nineteenth century was the rapid multiplication of the uses of rubber and an ever-increasing demand for the raw material. For several decades the world's needs were met by the Para district of eastern Brazil, but with steadily advancing prices as an inducement the entire Amazon Valley, and indeed all tropical regions of both hemispheres, have been ransacked in search of additional wild supplies. It is not yet true, as sometimes represented, that the natural product is exhausted or that a rubber famine is to be anticipated at an early date. Within the last decade the value of good grades of rubber passed from the neighborhood of 25 cents to a dollar and upward per pound, and the rubber-gathering industry met with an expansion sufficiently rapid to more than keep pace with the demand, so that a period of somewhat more moderate prices has ensued. But with a steady increase in the use of rubber in the arts and no very general improvement in the destructive methods of gathering the wild product, it is to be expected that this respite will be brief and that the question of the world's future supply will soon become more acute.

The preservation of the wild rubber forests is naturally receiving more and more attention in the countries in which they are so important a source of wealth, but measures of safety are least likely to be applied in the very remote and unexploited districts where they would do the most good. Rubber is still very largely a product of savage rather than of civilized industry; in fact, it is now by far the most important contribution of barbarous races to our industrial civilization. While this continues to be the fact there will be little change in the careless and wasteful methods of the past, but the appreciation of rubber forests as permanent sources of income may be expected to increase, so that the continued advance in the price of rubber no longer means merely the rapid extinction of wild rubber trees, but implies also increased interest in the protection and improvement of the more productive natural forests. Such a tendency is already manifest, especially in Brazil and in adjacent countries of South America, and probably means that the natural supply of rubber will never entirely cease, but will gradually become the basis for the development of scientific forestry in the Tropics. There is, however, no probability that any large proportion of the present producing areas will become permanent sources of supply, and the cultural production of rubber well deserves the serious consideration it is now receiving in all agricultural regions of the Tropics.

Rubber culture is no new or recent proposition, since beginnings were made nearly three decades ago. With an annual plant twenty years of experience would teach us much, but for dealing with long-lived trees that period is very short, and it need not be a matter of surprise that rubber culture is still in the experimental stage. Many cultural mistakes are still made with plants that have been in domestication for thousands of years, and the failure of the first attempts with rubber might have been predicted simply on the grounds of probability. Nevertheless, a distinct period of discouragement resulted, the effects of which are still felt and will doubtless remain until more detailed knowledge makes plain the possibility of avoiding the obstacles previously encountered.

Progress in practical matters as well as in purely scientific subjects depends much upon theories. On the failure of the first experiments, the theory that rubber trees could be profitably cultivated was discarded by many who came to the conclusion that planted trees will not produce rubber. This view is by no means extinct, especially among those who have abandoned rubber planting in disgust. An adverse opinion of this kind is popular with some because it serves as a general explanation of failure and spares the annoying suggestion of cultural errors and oversights.

Like other members of the vegetable kingdom the performances of rubber trees have been found to depend upon the conditions under which they grow, whether planted or self sown, unless they were injured in planting. In the American Tropics and in the East Indies the possibility of the cultural production of rubber has been demonstrated. This fact is giving the pendulum the return swing in the direction of sanguine expectations, and the assurance that rubber can be produced culturally is too often taken as a verification of the original estimates of yields and profits in spite of the fact that some of these have been disavowed by their authors. A future of easy prosperity for the rubber planter is held to be assured, and the opinion that rubber culture is still experimental is resented as blindly conservative. The lesson of the former miscalculation is forgotten by the new generation of promoters, and the fact that rubber trees have been found to thrive in a given locality is taken as sufficient evidence that they will meet even the most reckless estimates of productiveness and profits. The opening of large plantations under untried conditions in Porto Rico and the Philippines is advocated, and the investing public is assured, in effect, that the returns from rubber culture are to be so great that the exercise of ordinary agricultural skill and business caution is unnecessary, though the fact remains that a large measure of both is likely to be required if the numerous unsolved problems of the new industry are to be overcome without ruinously expensive experiments.

THE STATUS OF CASTILLA RUBBER CULTURE.

Many current discussions turn upon the question whether rubber culture is still in the experimental stage. This is the most frequent objection of those who lack confidence in rubber culture, and naturally arouses a strong protest from those who insist that rubber planting is the safest and most remunerative branch of agriculture.

It is true that rubber culture is no longer a new idea, since it was considered by the Government of British India as early as 1872, and Castilla was introduced into India in 1876. The Hon. Matías Romero, formerly minister from Mexico to the United States, also began to write on the subject of rubber culture in 1872. But the success of rubber culture can scarcely be demonstrated from the experiments of twenty or thirty years ago, since the results of few, if any, of these appeared sufficiently promising to justify their continuation. The plantation of Señor Romero was located in the Soconusco district of the State of Chiapas, in southern Mexico, and was early abandoned. The small plot of trees visited by the writer at La Zacualpa, some 60 miles northwest from Tapachula (see frontispiece), was probably planted as a result of the interest aroused by Señor Romero in this vicinity. The trees at La Zacualpa were set, however, as shade for cacao, and not as an independent culture. This was not the only experiment with rubber planting in the same region, but it seems to have been the only one which resulted favorably enough to call for the further investment of capital in the commercial production of rubber.

There have been, and still are, three general opinions regarding rubber culture. The first is that rubber can be produced at a profit wherever the trees will grow. The very frequent failure to secure rubber in paying quantities from planted trees gave rise to the second opinion that rubber could not be produced in cultivation. But these ideas are beginning to give place to the third and more rational view that rubber, like other agricultural crops, can be produced profitably only under favorable conditions, or, in other words, rubber culture may be said to have reached the stage when it can no longer be indiscriminately advocated nor indiscriminately condemned. If no other evidence were obtainable, the planted trees visited in Soconusco would prove that rubber can be produced in cultivation, and the investment of millions of dollars in Castilla culture in tropical Mexico and Central America may be taken as evidence that many are convinced that such production will be profitable. It is most unfortunate, however, that so many of those who have been attracted by the recent revival of interest in the subject have accepted the first view rather than the third, and have thus needlessly jeopardized their capital by attempting to grow rubber under conditions which the older experiments have shown to be more or less unfavorable.

When it is claimed that rubber culture has passed the experimental stage this should be taken to mean that the agricultural production of rubber has been demonstrated as possible. But from the agricultural standpoint it is even more true that rubber culture has only entered the experimental stage, since very little is known regarding conditions, methods, and results.

CASTILLA VERSUS HEVEA.

The preceding paragraphs may serve to explain why no decision has been reached on the very important question of the relative agricultural value of the different rubber-producing trees. It has been supposed thus far that the climatic and cultural requirements of the Para rubber tree (Hevea) and the Central American rubber tree (Castilla) were quite different, but the results of the present study seem to indicate that the differences, if any, have been much overestimated. The comparative experiments thus far carried on in botanical gardens have, at most, but a local value, and can not be accepted as final. In Java, for example, both Castilla and Hevea were condemned in favor of *Ficus elastica* (Assam rubber), but it now seems probable that the continuously humid mountainous district in which the experiment was tried was quite unsuited for testing the productive powers of Castilla, and probably of Hevea also.

It may be that no one rubber-producing species will attain any great or exclusive preponderance, but that different climatic and soil conditions can best be met by planting different trees. The wisest policy in untried regions will be to make experimental plantings of all of the more promising rubber trees. At present these are three in number: Castilla, Hevea, and Ficus. Manihot (ceara rubber) can probably be omitted from the list except for regions too dry for the others.

UNCERTAINTIES ATTENDING RUBBER CULTURE.

Some few rubber planters have not been contented to plant anywhere that the rubber trees could be made to grow, or even where they grew wild, but have emulated the northern farmers who planted young sugar maples close by the productive parent trees. Some of the plantations of Mexico seem to be outside the natural range of Castilla, as they have found it necessary to import the seeds from other districts. Others are in localities where the rubber tree grows wild but produces little or no rubber. For example, in Soconusco it would be entirely possible to establish a rubber plantation on the lower slopes of the mountainous and humid coffee district, where wild Castilla is not uncommon. Fortunately, however, rubber planting has been confined to the warmer and drier coast plain and to localities where both wild and planted trees have been found productive. That it will become possible by correct methods to produce rubber in countries where the tree is not native, and even in localities where the wild trees do not yield well, is to be expected, but it can scarcely be repeated too often that the planting of more than experimental quantities under untried conditions is a hazardous enterprise, to say the least, and not to be indulged in except by those who can afford to lose.

In the British dependencies of the Malay peninsula, Para rubber for several years past has enjoyed an era of rapidly increasing popularity, heightened recently by the fact that some of the earlier plantings have begun to produce and that good prices have been obtained for the samples shipped to Europe. But even yet the prize of success may escape, since it appears that the new East Indian Para rubber, though received with high approval by the importers, has been found seriously defective in quality.

> We have already expressed our opinion of samples of the cultivated rubber from the Malay states, which, while attractive in appearance, do not really resemble the fine Para rubber now in use. It is much softer than the Brazilian product, and of much shorter "fiber." It could not be used, for example, in thread, elastic bands, or any fine, pure gum goods. In solution, it quickly loses its tenacity, so that it would not do for high-grade cements. And it readily softens with age. Perhaps some of these defects might be removed by the introduction in the East of the methods of coagulation employed in the Amazon rubber camps, but we are disposed to believe that the Eastern planters have really produced a new grade of rubber, and that the Para article can never wholly be duplicated by them. It is to be understood, of course, that the rubber is valuable, and will find a ready market at a price which is likely to yield a profit, but such samples as have reached us, valued from the manufacturer's standpoints, would rank at least 25 per cent lower than fine Para.
>
> The good prices realized in London, doubtless, have been due to the cleanly appearance of the new rubber. And they have been based on the judgment of brokers, rather than results of practical tests in the factory. * * * The manufacturer's test is the one by which the value of this rubber will be judged finally, regardless of what may be the judgment of brokers to-day. We do not mean to dampen the enthusiasm of the planters, but there is such a thing as basing their plans upon estimates of profits that are impossible.[a]

It is certainly to be hoped that this disappointing report can be traced to some accident to the samples condemned, or that the quality

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[a] India Rubber World, 1902.

will improve as the trees increase in age. And yet it may not be a matter of surprise that with rubber, as with so many other natural products, perfection will be found to depend on some apparently trifling and long-overlooked peculiarity of soil or climate.

But whatever the true merits or prospects of the Para rubber industry of the East Indies, the above report well illustrates the vicissitudes of hope and failure to which new cultures must remain subject until scientific knowledge and practical experience have revealed the principal factors and shown something of their relative significance.

It is impossible to tell in advance which fact will be of directly practical importance in the development of a new and complicated subject like rubber culture. Nothing should be disregarded which tends to bring the rubber-producing species into relation with the facts which have been accumulated with regard to other plants, or which can serve as a suggestion for the solution of any of the all-too-numerous problems.

EXTENT OF THE CASTILLA RUBBER INDUSTRY.

At present the two centers of rubber culture are located in the East Indies, particularly in Ceylon and the British dependencies of the Malay Peninsula, and in Central America and southern Mexico. The India Rubber World has recently attempted a census of the rubber-planting stock companies of Mexico, and 26 of these have reported a total of 11,117 acres planted with 5,443,105 trees. The numerous companies which did not report and the many estates owned by individuals would probably bring the total area devoted to rubber to the neighborhood of 20,000 acres, or several times the space planted with Hevea in the East Indies. In the above estimate no account is taken of the numerous rubber plantations of the other Central American countries and the beginnings which have been made with Castilla in Colombia and Venezuela, which would mean an addition of several thousand acres to the estimate for Castilla.

CASTILLA IN THE WEST INDIES.

Castilla was introduced into the botanical gardens of the British West Indian colonies shortly after it was sent to British India in 1875, but rubber culture seems not to have become established in any of them, although numerous favorable reports from Trinidad and other islands have been published.

Castilla appears to produce good rubber and to do remarkably well in districts in Dominica where the average rainfall is about 70 inches a year. I am satisfied that the soil and climate of that island are suitable for the cultivation of rubber trees. * * *

We find the Central American rubber tree most useful in Jamaica, and I am recommending estate owners in some districts to plant these trees along their boundaries so that, if they are not used for anything else, they will make excellent fence posts. I am also advising them to plant it in their woods, so that the seeds may be distributed by birds. * * *

The Tobago rubber trees are grown on the cacao estates for shade purposes. On one estate the growth made by the trees was remarkable. The Central American rubber tree is the one chiefly cultivated.[a]

Castilla seems to have been introduced into eastern Cuba several years ago. A sample of rubber apparently of excellent quality has been received recently from Mr. Henry McManus, who states that rubber trees are growing on three estates—"Nuñez," "Palmarejo," and "La Consolacion"—in the vicinity of Baracoa. The annual rainfall in those localities is about 125 inches, and Castilla is said to thrive well.

CASTILLA CULTURE FOR PORTO RICO.

Studies of Castilla in its native home in Mexico have resulted in a more favorable opinion regarding the prospects of Castilla in Porto Rico, since it is believed that the requirement of continuous heat and humidity has been overstated. The north and south sides of Porto Rico have very different climates; some districts of the north may be too wet and much of the south too dry for Castilla. There are, however, particularly toward the southwest corner of the island, many places where the climatic conditions are not unsuited for Castilla and where experimental plantings should be made. If the soil and other local conditions do not prove unfavorable it will be possible to utilize for rubber culture much waste land too low and too much exposed to drought for coffee.

RUBBER IN THE PHILIPPINES.

The United States Department of Agriculture has received from the Philippines several samples of low-grade gutta-percha but no rubber, and it has not been supposed that native rubber trees exist in the islands. It has recently been announced, however, that a shipment of native rubber has been sent from Zamboanga, island of Mindanao, to a San Francisco firm. This rubber is said to be derived from *Ficus elastica*, the Assam rubber tree of the East Indies.[b]

That the Ficus is confined to Mindanao is scarcely to be expected in view of the fact that it has been reported on Formosa, far north of Luzon. It should accordingly be sought for on other islands of the group.

The existence of what may prove to be another rubber plant is indicated by the following paragraph from a recent letter received by

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[a] West Indian Bulletin, 2:112, 1901.

[b] India Rubber World, 27:115. The existence of the true *Ficus elastica* in the Philippines is unknown to botanists. Blanco's Flora states that an elastic gum is obtained from *Ficus rostrata*, a species later referred to *Ficus radicans* as variety *angulosa*.

this Department from Mr. Henry E. Neibert, an American teacher stationed at Jaro, on the island of Leyte:

There is a rubber plant indigenous to the soil here, the native name of which in the Binasaya dialect is *quiliquili* (pronounced *ke-li-ke-li*). Neither the natives nor the Spaniards seem to be aware of its commercial value, and have cut all easily accessible specimens at an early age for the columns which support their houses. Because it is a prolific plant is the only reason that it still exists.

It is not known that either Castilla or Hevea has been introduced into the Philippines. Seeds for experimental planting can be secured more easily from Ceylon or the Straits Settlements than from tropical America, but, as soon as the superiority of any one or more of the Mexican or Central American varieties of Castilla has been determined, a new supply of seed should be sent out. The suitability of some of the various soils and climatic conditions found in the Philippines for the culture of Castilla is to be expected. The character of the natural vegetation would enable one conversant with the subject to select the most favorable localities for experimental plantings, but until these have given evidence of success extensive undertakings will not be justified.

BOTANICAL STUDY OF CASTILLA.

DIFFICULTIES IN STUDYING TROPICAL TREES.

On account of their larger size it might be supposed that trees would be the easiest of all objects of botanical study, but this is far from being the fact. The size itself makes it difficult to observe a tree as a whole or to bring numerous individuals under the eye at once, as may be done with smaller plants. Moreover, trees can not be preserved as complete specimens, and only small fragments can be accommodated for ready reference in the herbarium. Nevertheless, the task may be said to be comparatively simple with the trees of temperate climates, where forests are relatively open and are frequently composed of only a few kinds of trees, or perhaps a single species. In the Tropics a natural forest of one species is practically unknown; hundreds of kinds grow indiscriminately mixed together. Crowded together in tropical forests trees have nothing like the shapes or habits they would assume if standing alone. All are putting forth, as it were, their best efforts to grow tall and thus secure as much sunlight as possible. Their leaves and branches are inextricably confused, interlaced with climbing plants, and encumbered with parasites and epiphytes. To cut down a particular tree may be impossible unless one is willing to clear a large neighboring area to permit it to fall. Unless the botanist finds a clearing, his opportunities for securing even the desired fragments of branches with leaves, flowers, and fruit may be extremely few, hence our knowledge of tropical trees is still in the early pioneer stages. Very recently the rubber tree of the Para district has been described and named as a new species distinct from the original *Hevea braziliensis*, which came from the upper Orinoco.

THE ORIGINAL DESCRIPTION OF CASTILLA.

The rubber tree of Mexico received a botanical description and name in a paper read by Cervantes before the Real Jardín Botánico (Royal Botanic Garden) of the City of Mexico, July 2, 1794, and printed with an engraved plate a month later in the Suplemento á la Gaceta de Literatura, a publication now very rare. According to Collins the British Museum copy lacks the illustration of the plant, but that of the Library of Congress at Washington is complete, and the figures are shown in photographic reproduction as Plate II of the present bulletin. An English translation of Cervantes's account of the rubber tree was published anonymously in 1805, but is said to have been the work of Charles Koenig, keeper of the mineralogical department of the British Museum. In this the name of the plant was changed from Castilla to Castilloa, an amendment which has become generally current, although justified by no recognized rule of botanical nomenclature. The tree was named Castilla in honor of Castillo, a Spanish botanist who died in 1793 while engaged in the preparation of a flora of Mexico. To modify Castilla into Castilloa was not the first change suggested, since a Mexican botanist had already proposed the word Castella in the same year in which Castilla was published. The question is, of course, of the slightest importance, and turns on whether the personal name should be latinized or not in forming from it the name of a plant. Castella and Castilloa would represent extremes of opinion, but few botanists, if any, would hold that Castilla was incorrect, and fewer still would recognize the right of anybody to change it. It will be apparent from comparison of our illustrations (see Plates IV to VII) that Cervantes's plate looks little enough like our photographs of the flowers and fruit of Castilla. Indeed, it need not be a matter of surprise if it should be found that they were taken from some different tree,[a] though there seems to be none known at present from Mexico from which they seem likely to have been made. The rounded clusters of fruits pointed with long recurved styles have considerable resemblance to those of some of the species of the South American genus Perebea, and the long, loosely-scaled staminate flower is very unlike those of the true rubber tree, though all these discrepancies may be due merely to careless drawing. That Cervantes was not personally acquainted with the rubber tree in nature seems to be indicated by his saying that the tree is "one of the tallest and most leafy which grow on the hot coasts of New Spain," and again that "the trunk is 3 or 4 yards in thickness."

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[a] Further studies show that more than one species of Castilla is being cultivated in Mexico and Central America, but the detailed results can not be included in the present report.

DESCRIPTION AND BOTANICAL CHARACTERS.

General appearance.—Like its relatives, the fig, the breadfruit, and the trumpet tree, Castilla has a characteristic general appearance and habit of growth which render it very easy of recognition. The trunk, with its rather smooth light-gray bark, has no very striking peculiarity, but the slender, simple branches, with their large oval leaves pendant in two rows, are similar to those of very few other trees. These features are perhaps most conspicuous in trees two or three years old, such as that shown in Plate VIII, since the leaves are larger and the slender branches are longer than in trees of greater size.

The temporary branches of Castilla.—The apparent impossibility that a young tree should have longer branches than an old one is realized in Castilla through the curious habit of self-pruning (Pl. X). Such a tree as that shown in Plate VIII has, in fact, no true or permanent branches, which generally do not appear before the third or fourth year. The temporay or false branches have a special layer of tissue at the base, which softens and releases them from their sockets, which are soon overgrown by the bark, so that even the scar becomes almost indistinguishable. The base of a fallen branch is marked with very fine edges and grooves radiating from the central pith, which is very small at the joint (Pl. XI). It is noteworthy from the botanical standpoint that these temporary or deciduous branches arise from the axils of leaves, while a more permanent or true branch appears as an adventitious bud at the side of the base of a temporary branch. On young trees it is very easy to distinguish temporary from permanent branches, from the fact that the latter are directed obliquely upward at an angle of about 45 degrees, while the temporary branch near which it arises is almost or quite horizontal. It has been supposed by some that all the true branches are permanent—that is, that they are not provided with the soft basal tissue which enables the others to separate so neatly; but the specimen illustrated in Plate XI shows that in one instance, at least, a branch of considerable size, and itself also branched, had been shed in the same manner as the smaller branches. The typical temporary branches seldom, if ever, attain an inch in diameter at the base, but on young trees they may be 10 or 12 feet long, while the leaves of such branches sometimes measure 18 or 20 inches in length. These dimensions are generally decreased to less than half after the tree has attained the mature branching form and is not dependent on a single axis for upward growth.

The leaves and leaf scales.—A detailed technical description of Castilla would be scarcely in place in the present paper, and is rendered unnecessary by the natural size illustrations (Pls. III to VII), which are far more effective than any description could be in conveying an impression of the details of the growing tips of the branches, leaves, flowers, and fruits.

The hairs or bristles which clothe the branch are of a dull greenish-yellow or brown color; they are sharp pointed, and with age become stiff enough to penetrate and irritate the skin of the hands like the fine spines of a cactus. Each leaf is covered, before it begins to open, by a large hairy bud scale, ribbed lengthwise (Pl. III). On falling away this leaves a narrow scar, which extends completely around the branch, but is much higher on the side away from the leaf which the scale covered. Below the scar is a row of small warts, at first white and then turning reddish. Similar leaf scars and warts are also found on the breadfruit and on the numerous species of figs.

The leaves are of a fresh light-green color. When young they are decidedly yellow below, because of the presence of numerous greenish-yellow hairs, somewhat softer than those of the branches. The fully expanded leaves appear less hairy because the hairs are distributed over a larger surface. They are most numerous on the midrib and larger veins, but are not confined to these. The hairs of the veins near the margin sometimes project past the edge in little tufts, which give the appearance of fine marginal teeth. The base of the leaf is composed of two broadly rounded lobes, which often extend past the stem and overlap. The larger veins are very prominent; they continue to branch and subdivide until a very delicate network is formed. The veins of all sizes are more hairy than the surface between them, but this is also distinctly hirsute. The upper surface appears smooth by comparison and is a much darker green in color. The veins are not prominent above and bear but few hairs. Under a lens it may be seen that the upper surface is not really smooth, but is set with very short pointed hairs, which render it rather rough to the touch.

The flowers and fruits of Castilla.—The flowers of Castilla are of two very different kinds. Both usually occur on the same tree, though young trees often produce only the male or staminate flowers. These are shown in natural size in Plates IV, V, and VI, and consist of scaly flattened pods, opening along the edge like a bivalve shell. Inside is a mass of creamy white stamens.[a]

The whole flower or head suggests a flattened fig, opening along the edge instead of at a small aperture in the middle. A pair of much smaller and more fig-like clusters of male flowers is often attached immediately under a cluster of female flowers.

The most conspicuous difference the writer was able to find between the Castilla of Alta Vera Paz in eastern Guatemala and that of the Soconusco district of southern Mexico is in the scales of the male

[a] In Modern Mexico for March, 1903, a correspondent writing from Oaxaca, Mexico, states that the flowers of Castilla are "of a brilliant scarlet," which would seem to indicate a variety distinct from those seen by the writer, unless the deep orange color of the fruits has been confused with that of the flowers.

flower clusters. Plate IV, from a photograph made near Panzos, Guatemala, shows scales much larger and more closely appressed than Plates V and VI, from photographs taken on La Zacualpa estate near Tapachula, Mexico. The difference is especially noticeable along the margins of the valves, where the scales of the Soconusco specimens are smaller and more numerous and project more than the others, as will be seen by a comparison of the plates.

The pistillate or female flower clusters of Castilla (Pl. VI) are flattened in the other direction, and might be described as broadly top-shaped. They are covered with scales much coarser than those of the staminate flowers, and numerous two-parted styles are exposed in the middle.

As the fruits approach maturity they enlarge and spread apart until the scales which formed the sides of the young flower cluster are carried back underneath to furnish a base for the rounded-pyramidal orange-colored ripe fruits (Pl. VII). The number of fruits which are able to mature varies between 15 and 25, and these are surrounded by an equally variable number of more or less aborted fruits, which shade off into scales by imperceptible gradations. At the rounded or truncate apex of the fruit is a minute cavity in which the withered remnants of the two-parted style are usually to be found.

The scales of the flower heads are velvety, with small and very numerous hairs, but the hairs of a few scales near the point of attachment are much coarser. The fruits are also very finely pubescent or velvety, the hairs being still more numerous and shorter than those of the scales.

The flesh of the fruit of Castilla contains numerous delicate fibers. It has a faintly sweetish taste, but is without appreciable flavor. The removal of the pulp leaves an ivory-white seed about the size and shape of the chick-pea or garbanzo (*Cicer arietinum*), but more regular in shape. The white outer wall of this seed is thin and becomes brittle as soon as it has dried a little. Underneath it is a still more delicate brown coat, marked with branching lines of lighter brown. The seed itself consists of two somewhat hemispherical cotyledons, with a very small plumule near the more pointed end.

It is doubtless owing to their very thin walls and rather fleshy texture that the seeds of Castilla dry out very easily and are accordingly very short-lived. The fruits ripen and fall to the ground at the end of the dry season, and the pulp assists in keeping the seeds moist until the beginning of the rainy season brings conditions favorable for their germination.

The milk of unripe fruits.—At present the rapid increase of rubber plantations renders the seeds valuable, but it is still permissible to raise the question whether the milk with which the unripe fruits abound may not be utilized. The fruits are produced in large quantities and, if the seeds were not in demand, would be of no value to the planter. The aggregate amount of milk they contain must be considerable, since on the slightest injury a large drop of creamy liquid exudes. This continues to be the case as long as the fruit remains green, but as soon as it turns yellow the milky juice disappears except from the seed itself. Presumably it is changed, as in figs and in the fruits of the family Sapotaceæ, into the juices which render the pulp attractive. The birds are apparently fond of the ripe fruits of Castilla. To dry the fruits gradually would probably mean the destruction of the rubber in the same way as in normal ripening, so that it might be necessary to cut or crush the fruit clusters to induce prompt drying, or to extract the milk and other juices by pressure, followed by washing and the separation of the rubber.

In case it should be found that rubber could be obtained from the unripe fruits, it would probably not be necessary to pick them by hand. They are so attached along the simple branches (Pl. XVIII, fig. 2) that several of them could be brought down by a single motion of a forked stick.

Prussic acid in Castilla seeds.—In examining the fresh seeds of Castilla a distinct odor of prussic acid was noticed, a fact which may have bearing upon the physiology of rubber, since the same substance occurs in the seeds of Sapotaceæ, the family which furnishes gutta-percha, and is also known to exist in the rubber-yielding genus Manihot, of the family Euphorbiaceæ, to which the Para rubber tree, Hevea, also belongs.

SPECIES AND VARIETIES OF CASTILLA.

HOOKER'S MONOGRAPH OF CASTILLA.

Sir Joseph Hooker wrote what might be termed a monograph of Castilla in 1885,[a] in which four species or varieties were described, though no new botanical names were assigned to them. The characters of the fruits were chiefly relied upon, and these are described as follows:

I. *Castilloa elastica.* Fruiting receptacle (in Honduras specimens) 1¼ to 2 inches in diameter; ripe carpels coriaceously fleshy, with pyramidal free pubescent crowns one-third inch high; crown 3 to 4 grooved laterally, with rounded angles and obtuse depressed 4-lobed tips. Seeds one-fourth to one-third inch in diameter; more or less immersed in the free crown of the carpel; testa white, papery when dry; cotyledons thick, plano-convex; radicle minute, superior.

The character by which I identify this with the plant of Cervantes is that of the free part of the ripe carpels, which that author describes as "apice excavato;" in all the other forms noticed below these crowns are acutely 3 to 4 angled, with acute tips.

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[a] On the Castilloa elastica of Cervantes, and some allied rubber-yielding plants. Trans. Linn. Soc., London, 2d ser., 2:209.

The reduced figure of the fruit given by Cervantes shows the character of the grooved sides and rounded angles of the carpels, but not their indented tips.[a]

II. The Caucho, or Darien plant. Leaves less thickly tomentose beneath. Fruiting receptacles 2 to 3 inches in diameter; crowns of the ripe carpels prominent, pyramidal, acute, acutely 3 to 4-angled. Seed one-third inch in diameter, more or less immersed in the free crown of the carpel.—Darien, on the Chagres and Gatun rivers.

III. Fruit referred to Ule, from the Belize Estate and Produce Company. Fruiting receptacle 1 to 1¼ inches in diameter; crowns of the ripe carpels prominent, acute, acutely 3 to 4-angled. Seeds one-fourth inch in diameter, more or less immersed in the free crown of the carpel.—Honduras and Nicaragua. This appears to be a small-seeded variety of the Darien species.

IV. Fruit of the Tunu or gutta-percha yielding plant, from the Belize Estate and Produce Company. Fruiting receptacles 2 to 2½ inches in diameter; crowns of ripe carpels very low, subacute, acutely 3 to 4-angled. Seeds one-third inch in diameter, immersed in the receptacle far below the crowns of the carpels.—Spanish Honduras.

COSTA RICAN SPECIES OF CASTILLA.

According to Koschny, four species of Castilla exist in the forests of Costa Rica, three of which yield rubber, while the gum derived from the milk of the fourth is not elastic, but becomes brittle and resinous. The general shape of the trees and their branches and leaves are said to be the same in all four kinds; the differences enumerated are those of the bark, the colors of which give the names to the three rubber-producing species.

Castilla alba, hule blanco, or white rubber, has a smooth bark which appears reddish white from a distance, owing to the presence of a thin white lichen. With age it becomes covered with coarser lichens and mosses and very difficult to distinguish from other forest trees. The bark and bast layer are thicker and softer than those of the other species; it is the most tenacious of life, and yields the most rubber. The milk is a thick fluid, and only about half of it runs down unless it is helped by the fingers; the rest remains in the cuts and dries down in six or eight days unless washed out by the rain while still fresh. Thus the tree does not easily bleed to death. The hule blanco is never found in the denser forests, but is abundant in more open places where the leafy crown can be exposed to the light and at the same time sufficient cover remains for the trunk. It is the only species suited for cultivation.

Castilla nigra, hule negro, or black rubber, has bark which is very rough and dark; also somewhat thinner, tougher, and more fibrous than that of *Castilla alba*. It gives considerable milk, but thinner and more fluid, and the tree often bleeds to death. On account of this greater susceptibility to injury it is not to be considered for cultivation. This species appears only in the undisturbed forests and is a true shade species. It is said also to occur with the other species, but is much less abundant, because it has more often died out.

Castilla rubra, hule colorado, or red rubber, has a bark so different from the others that it would not be taken for a rubber tree were it not for the other characteristics. The bark is distinctly thinner than in other species and the bast layer is inconspicuous.

[a] The range of the typical *Castilla elastica* is given as Mexico (south of 21°), Guatemala, Salvador, Honduras, Nicaragua, and Costa Rica, and the tree described by the Danish botanist Liebman as a distinct species, *Castilla costaricana*, is held to be the same.

Along the channels made by tapping it crumbles or easily separates. Externally it is smooth and has a reddish shimmer, especially on the branches and young trees. In contrast with that of the previous species it does not become fissured lengthwise, but is separated into transverse bands by shallow grooves. The bands, in turn, are beset with small reddish warts arranged in vertical and horizontal rows. Nevertheless, with the exception of the warts, the surface of the bark is quite smooth, without fissures of any kind. This species occurs frequently mixed with the others, usually less abundant than the white, but sometimes predominates. It may be that this is the cause of the poor results attained in the experimental gardens of Java and Ceylon, and that these were the more unpromising because this species requires to be shaded more than the white, but was probably planted in the open.

Castilla tanu, or hule tanu, is also called "gutta-percha" by the rubber gatherers. The bark is grayer but otherwise is very similar to that of the white Castilla, with which the leaves and habits also agree. The species is to be distinguished principally by the more prominent root folds or buttresses of the base of the trunk, which are distinctly thinner than with the other species; the upper edge is also thinner and sharper. This species does not occur in the San Carlos Valley, but first appears in the neighborhood of Bluefields on the Mosquito coast. On the Pacific coast it is in places very common. The milk flows in abundance, but becomes hard and resinous on drying. Although of no use as an elastic rubber it is possible that it might be adapted to some purpose, especially after the separation of the resinous constituents.

These summaries of Koschny's descriptions include all the distinctive points mentioned by him in order to facilitate the further study of the subject and also to make plain the difficulty which the planter would have in securing seed of the right kind, since the seeds of the different species are said by Koschny to be quite indistinguishable.

FIELD NOTES ON CASTILLA IN GUATEMALA AND SOUTHERN MEXICO.

Castilla probably grows wild in all the tropical forests of Guatemala, with the exception of those which are too wet. It is also found at considerable elevations, but the yield of rubber falls off as the altitude increases. In the Coban district of Alta Vera Paz there have been several experiments in rubber planting, but the altitudes are probably too great, and the coffee districts too continuously humid for good results; consequently rubber culture is now attracting little attention.

In the coast belt and the valleys of the Polochic and Motagua rivers several rubber-planting enterprises have been undertaken and abandoned. Only scrap rubber is obtained from either wild or cultivated trees. Either the milk is not produced in the same abundance or it is not held in the tree under the same pressure as in the rubber trees inspected later on the Pacific side of southern Mexico. It may be that two varieties of the trees differ in this respect as well as in the scales of the male flowers, as described above.

According to Hon. James C. McNally, consul-general of Guatemala, the productive rubber districts of Guatemala lie in the region about La Gomera, on the Pacific side near the coast. The low grade of the Guatemalan rubber as it comes to the market is explained by the fact that a very large proportion of it is stolen by professional rubber thieves who let the milk run down into a hole which they dig in the ground, thus allowing it to take up earth, stones, rotten wood, dead leaves, and other impurities. The planting of rubber trees as a regular industry is just beginning, but plans are being made for several large estates. Trees are said to have grown 21 feet in two years, and one tree (age unknown) is said to have produced 6 pounds of rubber. It is believed in this part of Guatemala that young trees do better when planted in the shade. The dry season in the Pacific coast districts is long and rather severe.

About Panzos and elsewhere in eastern Guatemala, Castilla had only begun to blossom at the time of our visit (April 4), but about two weeks later (April 20), on the way down from Guatemala City to the tropical belt of the west coast, the fruit of Castilla was found to be already ripe. The first trees were seen along the railroad below Escuintla, and others were found at San José. This would seem to indicate a much earlier season for rubber on the west side. Perhaps Castilla begins to form its blossoms at the opening of the dry season, which comes earlier on the Pacific side.

A few miles below Escuintla is a small orchard of rubber trees which must be at least ten or twelve years old. They had been tapped, but not extensively, and the experiment had apparently not been deemed promising enough to call for extension. A few Castilla trees were seen along the railroad between Ocos and Ayutla, and they became more frequent after crossing the Mexican border on the road between the last-named town and Tapachula. In the vicinity of Tapachula and again between Tapachula and La Zacualpa wild Castilla is very frequent in favorable situations in all uncleared tracts. In the forests about La Zacualpa, Castilla is a very common tree.

Along the road between Tapachula and the port of San Benito many Castilla trees have been planted, and in one place there is quite a long avenue, the rubber trees standing in a hedge of sour orange. These trees, although large and vigorous, are said to yield little or no rubber. The local explanation is that the soil of this neighborhood is a sort of hardpan not suited to rubber production.

Wild trees of Castilla were occasionally seen in the rather open forests near the coast, about San Benito, where palms of the genera Inodes and Attalea are also abundant. The rubber trees were small and rather spindling. One tree 4 inches in diameter "bled" freely when cut with a pocketknife. There had been rain the previous night. This coast region may have been originally forested with dense tropical growth, but this is probably not the case with the Inodes and Attalea districts. Some desert plants, such as wild crescentias, are found in the open places, but the woods are often thick. The land is very level, the upper layers probably washed down from the interior mountains and deposited on the beach sand.

No wild rubber was seen on the Isthmus of Tehuantepec between Juile and San Juan Evangelista. The vegetation here indicates a climate dryer than that in the vicinity of Tapachula. The somewhat more hardy plants of the rubber belt, Cecropia, Cochlospermum, Attalea, etc., are present, but the new elements are of the small-leaved desert or dry-climate types, with none of the humid tropical proclivities of the Tapachula region. The forest growth is also much smaller and the woods are more open.

Two small trees of Castilla were seen midway between San Juan Evangelista and San Miguel, on the new branch of the Vera Cruz and Pacific railroad. They were closely similar to the Pacific coast sort, but appeared rather unusually well fruited for young trees, and the individual ripe fruits seemed exceptionally large. The trees were slender, 4 or 5 inches in diameter, and had not been tapped. The country between the two points mentioned becomes more and more open; grazing is the only industry. There are occasional Attalea palms in the moister spots along streams, but Acrocomia is the only common palm. Acrocomia may be taken as a good counter-indication of wild Castilla, which seems to flourish only where there is more moisture and a vegetation more luxuriant than Acrocomia can compete with.

Both to the south and to the north of Perez station rubber trees grow wild, though they occur but sparingly, and all are of very small size compared with those of Soconusco, in keeping with the general reduction of the size and quantity of the forest growth, due probably to inferior soil and drier climate.

In one instance a large number of trees was seen in a small clump or thicket only an acre or two in area, but notwithstanding the almost complete exposure of many of the trees they were still of very slender habit. When young, however, they doubtless had undergrowth to contend with, but had been able to get well above this, owing to their greater vigor. There is no indication that rubber trees were ever abundant in the region about Perez. This view is also supported by the fact that the existing trees have not been killed or dwarfed by tapping, as in regions where the trees are sufficiently large and numerous to make rubber gathering profitable. That Castilla would grow, if planted, in the open grass land about Perez is very probable, but that it would thrive is not so likely, owing to the absence of the rich soil in which it prefers to grow, as seen in the more southern districts.

The oldest planted rubber trees in the Cordoba district of Mexico are said to be near Tierra Blanca. They are about 9 years old, and were to have been tapped experimentally in June, 1902. Sir Wetman Pearson, the English builder of railroads and harbors on the Isthmus of Tehuantepec, also has a plantation of about 100,000 trees of similar age.

The reported permanent moisture of the rubber district of the Isthmus of Tehuantepec is counter-indicated by the fact that the rubber trees uniformly drop their leaves very completely, both young and old, in the nurseries, as well as in the plantations. Many other of the native trees also drop their leaves in the dry season.

It was learned that there is a so-called *hule macho* in the vicinity of Trinidad and Buena Vista. It is recognized as having a fruit of a different shape from that of the true rubber tree, but it is generally thought to be the same. Seedlings of *hule macho* appear in plantations sown from seeds of wild trees collected in the neighborhood, which may obviously have come from wild *hule macho*, though it is commonly believed that they are the male sex of the rubber tree.

All the wild Castilla trees seen in the forests of Guatemala and southern Mexico might be described as of medium rather than of large size and of slender habit. The largest was near Tapachula (Plate IX), with an estimated height of 80 feet and a circumference of 7 feet at 5 feet from the ground. There can be no doubt that in some of the drier districts of the Isthmus of Tehuantepec and northward Castilla shares the reduced size and somewhat stunted growth of the tropical vegetation, which is here approaching the limit of its natural range. On the other hand, it can scarcely be doubted that in the more southern of the Central American Republics trees of Castilla attain a size unknown in Mexico. Thus, in Nicaragua, Belt speaks of trees 5 feet in diameter which yield as high as 50 pounds of rubber when tapped for the first time. Such a tree would of course be a veritable prize for the rubber gatherer, and it is easy to understand that in most localities they have all been destroyed, and with little prospect of being replaced as long as the rubber gatherer remains vigilant and the forests are unprotected. Whether the Castilla of Nicaragua and Costa Rica is the same species as that of Mexico is not yet known, but there is every probability that differences of some kind exist, and these are quite as likely to be differences of yield or of quality of rubber as discrepancies in shape of leaves or other merely "botanical" characters.. As soon as planters realize that a paying quantity of rubber is not, as so many have supposed, a necessary part of the economy of a tree they will better appreciate the fact that the production of rubber is a cultural problem as truly as the production of coffee or sugar and as dependent upon the same general factors. The conditions must be suitable for the plants and the plants suitable for the conditions. No plant variety will do equally well under all conditions, and it is almost as universally true that no two varieties will do equally well under the same conditions.

HABITS OF CASTILLA IN THE WILD STATE.

There is a popular impression that in order to domesticate a plant it is necessary to place it under the same conditions as in the wild state, but as a matter of fact our cultivated plants generally have much better conditions than their wild relatives. It is easy, however, to overlook some essential requirement of a new culture, and it is a distinct advantage to understand as thoroughly as possible the habits of a wild plant which it is desired to domesticate. The tamarack and the cypress, for example, are in nature confined to swamps, but they grow as well or better when planted on dry ground. The difficulty is that without human assistance they are unable to establish themselves on dry ground. Similarly, it has been inferred regarding Castilla that it is a shade-loving plant because it is found wild only in the forest. It is known, however, that it is thus limited in nature because the seed is so thin-skinned and short-lived that there is no possibility of its surviving exposure to the open sun on dry ground, and it is abundantly proved that young trees planted by man in the open are able not only to resist exposure to the sun, but that they actually thrive better than those planted by natural agencies in the forest. This fact should be sufficient for the purposes of practical agriculture, unless there are reasons for believing that more rubber can be produced in the forest. This is sometimes argued on the ground that Castilla is a native of dense forests and can not be expected to yield as much rubber under other conditions. If, however, it is true that Castilla, or at least *Castilla elastica*, is not a forest tree in any extreme sense of the words other reasons will be needed to justify shade planting.

THE RUBBER TREE AND THE TRUMPET TREE.

Castilla is a relative of the trumpet tree (Cecropia) and has a similar place in the general economy of nature. Cecropia is widely distributed in the Tropics, but is not looked upon as a true forest tree. It is what might be termed a tree weed. It shoots up with great rapidity, and is able for a time to keep ahead of the other vegetation which in most tropical countries promptly takes possession of land neglected after cultivation. Cecropia is thus one of many plants which have received indirect advantage from man's agricultural operations, and it is seldom found in great abundance except where larger growth has been cleared away. In the undisturbed forest it can not withstand the competition of the long-lived hard-wood trees and is found but sparingly, being limited to openings made by fallen timber, forest fires, changes of river channels, and other accidents which give it an opportunity for growth. The same appears to be even more true of Castilla. Scattering trees are probably to be found at greater or smaller intervals throughout the forests of low elevations, but there seem to be no indications that they exist in numbers except in forests of rather open growth, such as those which produce also the large palms of the genus Attalea, and which there is reason to believe do not represent a truly primeval condition or one of complete forestation, though the last clearing may have taken place centuries ago.

CASTILLA NOT A GENUINE FOREST TREE.

The native population of the Central American region is commonly supposed to have been much more numerous previous to the Spanish conquest, and the numerous and widely distributed ruins prove the former existence of relatively civilized communities in localities which even in the time of Cortez were apparently forgotten and overgrown with forests as they are to-day. But notwithstanding the former civilization of these regions, there seems not to have been found anywhere in Central America an indication of permanent agriculture, such as terraces, walls, or irrigating ditches. The agriculture of the ancient Indians was probably like that of the modern, in that each head of a family cut down and burned each year a new piece of forest to plant his farm or "milpa." Where the population is large and old forest is no longer accessible the second and successive growths are cut at intervals of a few years until the tropical rains have washed away all the fertile surface soil and the district becomes, for the time, a desert, and is abandoned by its human inhabitants. Such deserted country is covered first by a coarse grass and then by a scattering growth of pines, which are in turn crowded out by an invasion of tropical forest vegetation, at first in the more sheltered and humid ravines and valleys and then over the whole area. At low elevations the trumpet tree and Castilla form a part of the vanguard of the new growth, and the Attalea palm is its most striking species. But it is only a question of enough time for these and their accompanying species to be overcome and well-nigh exterminated by what may be termed the permanent forest.

When one sees the Indians of to-day clearing, burning, and planting precipitous and scarcely accessible cliffs it becomes easy to believe that little fertile land in Central America, if any, is occupied by truly primeval forest, and easy also to understand that the abundance and wide distribution of Castilla may depend upon human activity even more than upon natural agencies. Arguments based upon the assumption that Castilla is a genuine forest tree may accordingly be dismissed as of little agricultural significance.

Mr. O. H. Harrison, manager of the rubber estate at La Zacualpa, was much interested in this view of the place of Castilla in nature, because he had already noticed that clusters of wild Castilla are met with in the forest only where some natural or artificial clearing had been made. Moreover, an examination of the literature of rubber shows that the facts are not new, though their significance has been concealed by the explanation which accompanies the following original account of the details learned from the rubber gatherers of Nicaragua:

> The trees prefer humid and warm soils, but not marshy, clayey, or gravelly ground, and the presence of these trees is looked upon as an indication of a fertile soil. It is not distributed irregularly through the forests, but sometimes in little groups, more

or less isolated, such a group being termed a *mancha* (spot). This grouping is the normal state, and is believed to be caused by monkeys dropping the seeds near an isolated tree, as they are very fond of the pulp by which the seeds are surrounded. The trees are distributed in vetas (veins) or bands, either in a north-to-south or east-to-west direction, the first probably caused by monkeys, by the trees being on a declivity, or by water, and the second by the wind, which daily blows in that direction. This irregular distribution has led M. Levy to the opinion that in cultivation they should be interspersed between other trees rather than form separate plantations, as he thinks that this sympathetic and antipathetic tendency should not be lost sight of. The hule is often near water courses, and nearly always on the banks. Trees of small groups give a better net produce than those composing large groups.[a]

From the scientific standpoint these explanations appear quite inadequate, since the causes which they suggest are those which are in continuous operation, and if effective in spreading Castilla at the expense of other forest trees would have given it a general preponderance long since. All the facts are, however, comprehensible on the supposition that the growth of Castilla depends upon opportunities which are relatively infrequent in undisturbed forests, as compared with regions inhabited by the Indians and subject to their primitive agriculture.

IMPROVEMENT OF RUBBER TREES BY SELECTION.

Instead of being able to dispense with agricultural knowledge, skill, and caution, the rubber planter needs an extra supply of these, since, without the advantage of adequate experience, he has the added responsibility of choosing favorable natural conditions, applying correct cultural methods, and securing the plants most suitable for the circumstances under which he must operate. That American planters have given their attention so exclusively to Castilla, and those of the East Indies to Hevea, is not the result of any demonstration of the cultural superiority of the one tree or the other, and the desirability of many other species reported as promising remains to be determined. It is entirely possible that no one species will be found to have a superior value under all conditions and be planted to the exclusion of all others. Rubber, like starch, is produced in nature under varied conditions, ranging between deserts and swamps. The number of cultivated rubber plants will probably never equal that of the starchy cereals and root crops; but there is the same practical reason why the cultural requirements, hardiness, vigor, and productiveness of the different rubber plants should be considered, and not merely those of the distinct genera and species, but those also of the differing varieties or races into which each species will be found divisible by cultural selection.

It has been found possible with many plants to increase the average percentage of starch, sugar, or oil through the planting of selected seed or cuttings, and there is every probability that the same will be

[a] Collins, Report on Caoutchouc, pp. 14 and 15.

true of rubber. In fact, the great variation in the amount of rubber both in wild and in cultivated trees is itself an indication that a ready response to selection may be expected. The selective improvement of trees propagated from seed is, however, a very slow process, owing to the time required to bring the generations to seed-bearing maturity. With Castilla much more prompt results could be obtained by the use of cuttings made, of course, from true or permanent branches. It would be excellent policy on the part of planters to set as large a part of their plantations as possible with cuttings from their most productive trees, and to watch for the best "milkers" in each generation, just as the sugar growers test the sugar content of individual canes and of individual beets which are to be used for propagation. The selective improvement of rubber plants may be pushed forward without waiting to find out what the function of rubber is or what determines its formation in the plant, since all that the planter needs to know is that rubber is present in more than average quantity in certain of his trees, and he may expect that by propagating from these under the same conditions a higher average of production may be secured.

PROBLEMS PRESENTED BY THE LATEX, OR "MILK."

Of what use is the rubber milk to the trees, or why do the trees make rubber? These are the questions which seem to underlie the scientific investigation of the cultural production of rubber. At first it was taken for granted that the elaboration of rubber is the special function of the rubber tree, an idea apparently indorsed by some of the tree-planting companies in such statements as the following:

> You can no more grow a rubber tree without the rubber milk in it than you can grow a sugar-maple tree without the sugar sap in it. The growing of rubber trees in their own soil and climate is just as practical, just as safe, and just as sure as gathering elm seed and growing elm trees therefrom.

Rubber is not, however, the fruit of the rubber tree, except in the financial and commercial sense, and even the slightest experience in agriculture should have prevented the inference that because a plant thrives when young it is certain to reach a productive maturity. Many of the early experimenters in rubber culture have found to their cost that the Central American rubber tree, at least, can grow with the most promising vigor and yet fail to deliver any approximation of the estimated quantities of gum. Indeed, this fact might have been learned with vastly less expense of time and money by consulting the native rubber gatherers, who are thoroughly aware that many "ule" trees give no return for tapping. The realization of this simple and fundamentally important fact has been delayed through existence in some of the Central American rubber districts of a second species of Castilla," called by the natives "ule macho," or "male rubber," because it gives little or no milk.

Possibly owing to the suggestion of the obviously distinct sexes of the tropical papaw, or melon tree, the idea of sexuality in plants is widely prevalent among the aborigines of tropical America and their Spanish-speaking descendants, who thus have in the word "macho" a ready explanation of unproductiveness.

Perhaps it has never occurred to any of the native rubber gatherers to insist that the white man should understand the difference between the "*ule macho*," which is a distinct species (*Castilla tunu*), and the "*ule*" termed "*macho*," because it does not yield milk, though not in other respects different from the productive trees. Again has a little learning proved dangerous, in that the existence of a sterile species of Castilla has served as a general explanation of differing yields of rubber, the true causes of which still remain to be discovered.

That varietal and individual differences of yield will be found inside the genuine rubber-producing species is, of course, to be expected, but there is also every probability that conditions, whether natural or artificial, may have a profound influence on the all-important feature of rubber production, so that we are brought again to our original question of causes determining the formation of rubber.

EVOLUTIONARY ARGUMENTS REGARDING LATEX.

Some have insisted that the solution of the problem lies in discovering the use of the rubber to the tree, on the ground that natural selection brings into existence only useful characteristics. This theory has encouraged speculation, and numerous attempts have been made to frame a general explanation of the function of latex, or milky juice in plants. Such, however, is the diversity both of the thousands of latex-producing plants and of the substances which the various kinds of milk contain, that any explanation sufficiently general to accommodate all might have little practical bearing on rubber culture. Indeed, there is no assurance of unity of causes and methods of formation of milk in the several hundred species of rubber-producing plants of diverse families and conditions of growth, and we can even go farther and say that Castilla itself demonstrates that the production of milk and of rubber may be of no very serious importance in the plant economy, since apparently normal growth and reproduction are accomplished with little or no rubber. Furthermore, we have no assurance that the discovery of the function of the latex would bear directly upon the question of rubber production, since it does not appear that the mechanical qualities which we value in rubber, notably its elasticity and toughness, are of use to the tree or that they exist in the living latex. Commercial rubber is certainly a very different substance from the creamy mass which first appears when coagulation sets in, and numerous changes may have taken place before even this stage is reached. Between the vegetable and animal milk no complete analogy can be maintained, but it serves to illustrate the present point if we think of the rubber not as the curd which coagulates from the milk, but as the butter which may be separated both from the curd and from the still more watery constituents of the milk. As the churned butter is different, both mechanically and otherwise, from the fat globules floating in the milk, so does rubber differ, and probably to an even greater extent, from the semifluid globules of the latex emulsion. Rubber, as such, has no function in the plant, and there is nothing to indicate that the qualities which make it valuable to us are of any significance in the vegetable economy. Furthermore, it appears that at different stages of the Castilla tree, and even in different parts of the same tree, the substance which becomes rubber may be replaced by another, which hardens with exposure into a worthless, nonelastic resin; indeed, resin and not rubber is a constituent of the latex of the numerous relatives of the rubber-producing trees.[a] It appears, then, that to trace any direct connection between rubber and the economy of the tree is likely to be very difficult, if not quite impossible, and in general reasoning on the subject the inquirer must be content to learn, if possible, the causes which influence the quality and quantity of latex in trees known to produce rubber.

FUNCTIONS ASCRIBED TO LATEX.

The nature and functions of latex in plants are difficult problems. Many dissertations have been contributed to swell the experimental and controversial literature of the subject. Many interesting details have been discovered regarding many lactiferous plants, and many suggestions and theories have been contributed to the subject of plant physiology, but thus far no very practical result seems to have been reached in this direction. Indeed, progress may have been impeded by the idea that it is necessary to postpone the investigation of concrete problems of rubber production until a general theory of the function of latex or milky juice in plants can be formed. Very different suggestions regarding the uses of latex have been defended by different investigators on the basis of studies of different plants. The first observer compared them to the blood of animals and described the globules of gum as corpuscles, a highly fanciful notion which later writers have so zealously disavowed that they have felt it necessary to deny any circulation at all. Some have held that the milk tubes are reservoirs for the storage of elaborated food materials, while others

[a] In the State of Vera Cruz, Mexico, grows a large-leaved species of Ficus, the milk of which coagulates promptly into an elastic substance like true rubber, but the elasticity soon disappears when the gum is exposed to the air and repeatedly stretched between the fingers.

believe that latex is an excretory or waste product, even to the proteids, starch, and sugar with which the milky fluid is commonly charged. Protection against insects and snails has also been urged as the function of latex. One of the most recent writers on the subject[a] reviews and dismisses all the previous suggestions apparently for the reason that none is of general validity and, after detailing numerous observations of his own, comes to the following disappointing conclusion:

> It seems impossible to discover what is their function or to ascertain if there is one function common to all laticiferous tubes until microchemical methods are vastly improved or until analyses of latex in its various stages are made.

Obviously, however, there is no reason why it must be believed that all the functions of all milk tubes are the same, or why one function should exclude another. That insects, such as leaf-cutting ants, should not be able to attack rubber trees because the gum would disable their mouth parts might be an important advantage in Central America, but would not explain rubber in African plants not subject to the depredations of these insects. The most that can be done is to learn the uses of latex in one plant at a time, without anxiety as to whether or not a general function for latex in all plants will be discovered.

THE STRUCTURE OF LATEX.

All the foregoing suggestions and many others seem to have been made before it occurred to anybody to treat the simple but fundamental question of how the rubber is formed in the milk-bearing tubes. But there is one author at last who has appreciated this point and who has discovered by a close microscopical examination of the rubber globules that each is surrounded by a thin coating of protoplasm, with a small nucleus on one side.[b] This means that the globules of rubber are produced in the same manner as globules of fat and resin, and like the granules of starch and the crystals of lime, oxalic acid, and other substances which are laid down by the protoplasm of plant cells. If the rubber appeared in the tubes merely by chemical action or because the constituent elements were brought together, this would be an indication favorable to the synthetic production of rubber in the chemical laboratory, and it would mean also that the milk is, if not a solution of rubber, at least a solution of the constituents of rubber.

There are, however, no observations to indicate that rubber exists in plants except in the form of minute globules, so that the milk resembles that of the cow in being an emulsion. The globules are not,

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[a] Percy Groom on the Function of Laticiferous Tubes, Annals of Botany, 3: 157, 1889.

[b] Studien über den Milchsaft und Schleimsaft der Pflanzen, von Prof. Dr. Hans Molisch. Jena, 1901.

however, naked and free, but each is surrounded by a layer of protoplasm which must contribute a part of the "albuminous constituents" of the latex, if it does not supply all, though this does not make it easier to understand the recent statement of Dr. C. O. Weber[a] that such materials are not coagulated by boiling. It might be thought that the boiling coagulates the protoplasm of each globule separately and that the rubber is released afterwards and rises to the top, but Dr. Weber's statements would not bear this interpretation, though the absence of an explanation of the supposed failure of heat to coagulate any of the albuminous matter leaves the impression that this account of the details is not complete.

SEASONAL INFLUENCES ON LATEX.

No theoretical consideration need interfere with the recognition of any relation which can be proved to exist between the amount of latex or of rubber obtainable from Castilla and the climatic conditions under which the trees are found. The most direct evidence of such climatic influence is to be found in the seasonal changes in the latex. Such differences in the rubber content of the milk at different seasons has received little attention from recent writers, though it is not a new fact, since a detailed statement was published by Collins over thirty years ago:

> In Nicaragua it is found that although the hule yields the juice at all seasons, the most favorable season is April, when the old leaves begin to fall and the new ones appear. During the rainy season, from May to September, the richness of the juice diminishes. From that time to January the rain diminishes and the milk increases in richness, and the tree prepares to flower. The fruit appears in March, during which month and the succeeding one the milk is at its richest. The yield of caoutchouc contained in an equal quantity of milk would in April be 60 per cent more than in October.[b]

The increased richness of the milk in the dry season seems to be recognized in all districts where the dry season is long enough to permit the effect to become appreciated, but in localities where the dry weather in which tapping can be done is short there is at once less difference and less opportunity for it to become evident. Where the dry season is long, as at La Zacualpa, the flow of milk becomes small and tapping is deferred until some rain has fallen, when the quantity and quality of the milk are both at their best. The popular idea is that as the dry season advances the milk becomes too thick to flow, and that during the rainy season it becomes too poor in rubber to pay for tapping. The fact that the latex becomes richer during the dry season does not prove, of course, that the additional percentage of

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[a] Tropical Agriculturist, 22:443, January, 1903.

[b] Report on the Caoutchouc of Commerce, 1872, p. 15.

rubber is a measure of protection against the dry weather. It may be that the rapid growth which goes on in the rainy season uses up the rubber, while the cessation of growth in the dry season permits it to accumulate. This possibility does not, however, exclude the other, but seems rather to strengthen it, since there are other reasons for believing that the possession of latex is an advantage in the struggle against drought. Several such facts were noticed during a recent visit to southern Mexico.

LATEX IN DESERT PLANTS.

The plants able to make the most vigorous growth and put out flowers and new leaves at the end of the dry season, even in the cactus deserts about Tehuantepec, belong to the genus Jatropha and are near relatives of the Ceara rubber tree, *Manihot glaziovii*. Also Prof. H. Pittier says that on the dry Pacific slope of Costa Rica the Ceara rubber tree produces rubber, but refuses to do so in the humid district of Turrialba, although it thrives well there.

In the cactus desert about San Geronimo to the northeast of Tehuantepec is another euphorbiaceous plant with naked green stems a yard or more in length and reddish unsymmetrical flowers. The stems are rich in a milky juice, which rapidly coagulates into a substance much like rubber, but lacking elasticity. The plant was quite leafless, but was blossoming at the end of the dry season. After the milky Euphorbiaceæ, the most flourishing desert plants were the Apocynaceæ, also with milky juice. The leguminous plants of the desert do not have latex, but they are noted for their richness in gums and resins, which are similarly formed and may have similar functions in the plant economy.

The most striking suggestion of the utility of latex as a protection against drought was noticed in a cactus of the genus Mammillaria, found nestling in the crevices of the bare, black rocks of the fiercely heated hillsides about Tehuantepec. The Mammillarias differ from all other members of the family in having a thick, milky juice, which becomes very sticky between the fingers, though showing no signs of elasticity. It will be difficult to avoid the conclusion that in this instance the milky juice is the special character which has enabled the Mammillaria to excel all its relatives in resistance to desert conditions of extreme heat and dryness.

A step in the same direction seems also to have been taken by a large, straggling Opuntia found near San Geronimo. Instead of the watery juice found elsewhere in this genus, a knife cut brings out a thickish, opalescent sap, which rapidly coagulates into a somewhat resinous substance and quickly seals over the injury.

WATER STORING AS A FUNCTION OF LATEX.

As already stated, the recognition of a relation between latex and dry weather has been hindered rather than helped by the attempt at framing a theory of the use of latex to the plant; but a few writers have appreciated such facts as the above, and have been inclined to look upon the storage of water as the long-sought general function. The following extract affords an instance:

> If the formation of laticiferous tubes has been called forth in all plants possessing them to perform a common function, then I am inclined to think the idea of their serving as channels for holding water in reserve as one of the most plausible. Laticiferous plants are markedly characteristic of tropical regions, where transpiration is great. The development of a system of tubes running throughout the plant to be filled with water during the wet season and then to be gradually drawn upon during times of drought is intelligible.
>
> Warming, in a paper in the Botanical Gazette for January, 1899, entitled "Vegetation of tropical America," mentions lianas and other plants of tropical forest and scrub as often lacticiferous, and says: "Most likely latex serves several purposes, and one of them, I suppose, is to supply water to the leaves in time of need when transpiration becomes too profuse."
>
> From our experiments in Ceylon we found that the quantity of latex extractable from incisions in the trunks of Hevea trees varied considerably with the time of the year and seemed to depend largely upon the available moisture in the soil. After heavy rain the exudation of latex is much more copious and thinner, looking as though the vessels had become surcharged with water.
>
> As the necessity for a reserve of water increased, the laticiferous system would tend to become more extensive and more intimately associated with the surrounding tissues. The genus Euphorbia chiefly inhabits dry regions and is one of the richest in latex.
>
> This view does not explain the proteid or starch grains of latex, yet I think it is one to be borne in mind in studying the rôle of latex in plants, and hitherto it has in the main been disregarded. If latex does serve as a water reserve, then perhaps it is chiefly valuable for the growing organs.[a]

This view has, however, met with no general acceptance, and has obvious difficulties, the most important being that the amount of water actually stored or present at one time in a tree like Castilla would not long suffice for necessary transpiration. It avails little for such a plant to store unless it is also possible to husband the supply. At present, however, there seems to be no practical suggestion of means by which latex rich in rubber could better assist either in storing the water or in preventing transpiration, but of these alternatives the facts seem to be much more in favor of the latter. Apart from the slight increase due to growth, the contents of the trunk must remain of approximately the same volume. The increased pressure to which is due the increased flow of milk after the rains begin does not require a large increase of the volume of liquid in the tree, and is in all probability greatly assisted by its greater fluidity, which enables it to flow longer distances to the cuts, the capillary friction being decreased.

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[a] Parkin, Ann. Bot., 14:212–213, 1900.

The greater humidity of the atmosphere would also tend to the continuation of the flow in the rainy season by preventing the drying or the coagulating of the surface of the cuts, though the importance of this factor has not been determined.

That the increase of the rubber content of the latex serves as a protection against drought is also rendered somewhat more probable by the fact that Castilla has several characters serving the same purpose. The development of hairs upon the branches, bud scales, leaves, flowers, and fruits is much greater than is usual among related plants. The self-pruning of the branches and the rapid covering of the scars are also exceptional and of obvious utility in reducing transpiration, and the prompt falling of the leaves in situations where the water supply becomes deficient shows even better the sensitiveness of Castilla to drought.

SIGNIFICANCE OF MULTIPLE TAPPING.

The latex problem acquires new interest from the recent demonstration that Hevea, at least, continues not only to yield milk by the daily renewal of the wounds, but that the quantity actually increases for several days. This might seem to favor the idea that the latex has a nutritive function, the additional quantities being assembled, as it were, to repair the injury. On the other hand, the supposition that the rubber hinders evaporation would also work equally well and affords the additional suggestion that the greater evaporation from the wound may assist in collecting the rubber about it, the yield increasing as the widening of the wound increases the surface of evaporation until the available supply of latex has been depleted.

CLIMATE AND RUBBER PRODUCTION.

A CONTINUOUSLY HUMID CLIMATE NOT NECESSARY FOR CASTILLA.

The study of Castilla furnishes evidence that with this tree there is a relation between climate and rubber production, and that this relation is the opposite of that commonly supposed to exist.

The vast quantity and high quality of Para rubber have naturally given Brazil the chief place in the thoughts of those interested in rubber, and it is one of the best established traditions of the subject that the native home of rubber is in the vast, periodically overflowed valleys of the Amazon and its tributaries; and the common failure to appreciate the diversity of the rubber-producing trees gave this idea very general acceptance.

Practical experiments in Central America soon showed, however, that Castilla will not thrive in swamps or where the drainage is deficient, and this fact is generally noted as a cultural difference between Castilla and Hevea, though the need of continuous humidity for Castilla is still insisted upon. The point has even been carried so far that some of the companies doing business on the Isthmus of Tehuantepec, where there is a very distinct dry season, still feel it necessary to omit this fact from their prospectuses or to represent their plantations as always moist. The incorrectness of this claim not then being realized, the extent of the dry season of the west coast of Guatemala and the adjacent Soconusco district of Mexico was observed with much interest.

GREATER ABUNDANCE OF CASTILLA ON THE DRIER PACIFIC SLOPE.

The total rainfall of a place affords but the slightest intimation of its climate in relation to vegetation. A sudden, heavy shower may wet the soil much less than the same amount of water falling as a steady rain, and in the supply of water to plants the difference is even greater; the period during which the atmosphere and soil are moist is of importance to them, but not the amount of water which patters off their leaves or falls into the rain-gauge. Humidity even to the point of saturation for six months may be of no avail to plants unable to survive an equal period of drought. The lowland forests of the west-coast districts of Guatemala and southern Mexico, while composed in the main of the same tropical elements as those of eastern Guatemala, yet showed a striking deficiency of plants requiring continuous humidity.[a] Nevertheless wild Castilla seems to have existed in the past as in the present in far greater abundance, the wild product having long been an article of export in quantity far more considerable than from the eastern districts.

FREER FLOW OF MILK IN DRIER REGIONS.

A second fact contrary to the popular supposition that rubber production is confined to continuously humid climates was encountered when it was found that, in spite of the greater dryness, the milk flows down from the rubber trees of Soconusco with a freedom unknown in eastern Guatemala, where it merely oozes out into the gashes made by the "uleros." Dr. Paul Preuss, who studied rubber culture in Trinidad, Mexico, and Central America for the German Colonial Society, did not see rubber flow down from the wounds made in tapping, and seems to have left America in some doubt as to the reality of this phenomenon. He explains that the milk of Castilla behaves very differently from that of other rubber trees. The "fish-bone cut" to which he had been accustomed was found in Trinidad to

[a] Such are the filmy ferns, or Hymenophyllaceæ, and forest species of Selaginella; also many Orchididaceæ and Piperaceæ, largely absent from the forests between Ayutla and Tapachula, and also from the vicinity of La Zacualpa. Moisture-loving plants increase with altitude as the more humid coffee districts are approached, but at no lowland locality visited do they exist in any such abundance as in the forests of the valley of the Polochic River, in eastern Guatemala.

be useless with Castilla, since the milk flowed out as a liquid only in the first few drops and soon turned into a pulpy mass, which remained in the grooves and had to be wiped out with the finger. Dr. Preuss says:

In a Castilla plantation near San Salvador the manager stated, on my inquiry, that there are hule trees the milk of which is completely liquid and others of which the milk is thick and does not run down. I had both kinds of trees pointed out to me, but could recognize no difference in trunk, leaves, or fruits. All the trees, which I tapped later, always showed the thick milk.

In Guatemala, however, trees were pointed out to me on two plantations which, with exactly the same appearance in leaves, fruits, habits, etc., still had a completely different behavior. On tapping there flowed out in abundance a thinly liquid milk, which, however, contained no rubber, or only very small traces of it. Of such trees there were many on both plantations. They had been specially marked, and were never tapped; naturally their seeds were also not sown for new plantations. The statement that the milk of Castilla, that from which good rubber can be obtained, runs down the trunk into vessels, I have often heard asserted with positive assurance. I have never been able to convince myself of it, and can only suppose that it is a case of two different varieties, with one of which I have not become acquainted.

DECREASE OF MILK WITH ALTITUDE AND CONTINUOUS HUMIDITY.

That rubber milk is obtained with greater freedom on the drier western coast shows that continuous humidity is at least not indispensable, but it does not prove that the larger production is due to the drier climate. There may be, and probably are, differences in the trees of the two regions, though these have not been detected. But that there is a climatic element even on the west coast is made plain by the fact that as the coastal plain is left behind and the slopes increase in altitude and humidity the production of rubber gradually declines. At an altitude of about 1,800 feet on the Esmeralda coffee estate, only a few miles from La Zacualpa, wild Castilla trees apparently normal in other respects yielded milk very sparingly, while at an elevation of 2,500 feet no milk dropped from the cuts. Castilla trees grew vigorously and attained a diameter of 15 inches in twelve years at "Quien Sabe," in the coffee district above Tapachula. The trees grow naturally up to 1,500 feet and beyond. Above 1,000 feet the rubber gatherers do not expect to find much rubber. Trees planted at an altitude of 2,000 feet from seed brought from the coast do not yield rubber.

The fact that Castilla yields little or no milk in elevated situations is commonly recognized in Soconusco, though it is not necessary to accept the popular impression that the difference is due to the mere fact of elevation. The temperature being lower and the atmosphere more humid, there is less rapid transpiration of moisture and less need at once of means of resisting dryness and of maintaining the high pressure of fluids found in trees growing near sea level.

Decrease of temperature would also mean a decreased effect from dryness. If this interpretation of the function of rubber be correct, a region like the Isthmus of Tehuantepec, which might be suitable for coffee at relatively low elevations, would not for this very reason be favorable for rubber. It is also not to be assumed that a region in which the rubber tree grows wild is favorable for the production of rubber. The case is quite different from that of a seed or fruit crop. A plant is not likely to become established in a region where it can not ripen seed, but if rubber is an adaptation against unfavorable conditions, it might be dispensed with where the unfavorable conditions do not exist. That latex serves in Castilla as a protection against drought does not mean that it may not have other functions here and elsewhere. The problem of rubber culture is to encourage the formation of latex by placing the tree under suitable conditions.

In a dry atmosphere the transpiration—that is, the moisture given off by the leaves—is much greater, and as this water is taken up from the soil the amount of salts and other soluble substances taken into the plant with the water is also much increased. It is by no means impossible that substances obtained in this way are used in the formation of rubber, and if this be the case the tree would have, as it were, an automatic protective device; the drier the weather the greater the quantity of rubber-forming materials and the greater the protection against dry weather. It is possible even that the thickening of the milk might finally impede the circulation of water and be itself the cause of the falling of the leaves, as Parkin observed with the leaves of Hevea. The falling of the leaves in the dry season would thus be an indication of conditions favorable for rubber culture rather than the reverse, as some have supposed. It is not at all impossible that a rubber tree might grow best in a region where it would not yield the maximum quantity of rubber, and, conversely, it may be found that the most rapid growth of the trees does not insure the largest yield of rubber. If it be true that rubber is a dry-weather product, the limitations of rubber culture on this side are in securing enough rain to permit rapid growth. One problem would be to find out how much of a dry season is necessary for best results. Too much dry weather would mean slow growth, too much rain decreased formation of rubber, and these factors would vary even in the same neighborhood and with different seasons. The prospects of particular localities for rubber can not be ascertained by the tapping of a few trees in each at the same date or in the same month. A tree in which the pressure in the milk tubes was too low or the milk too thick to flow out in the dry season might yield abundantly at the beginning of the rains, while in a more humid locality the fluctuations would be much less.

That rubber could be obtained from one tree in the dry season and not from another might mean merely that the former had access to a larger supply of water and was thus able to maintain a greater latex pressure. Such questions will need to be studied in detail after uniform methods of tapping and pressure measurement have been devised. This need not obscure the fact that, unless tapping be done at the most favorable date, the productiveness of rubber trees and the localities in which they grow may be misjudged very easily.

CASTILLA IN NICARAGUA.

The opinion that the production of rubber by Castilla is favored by a dry season is based, as yet, only on observations made in Guatemala and southern Mexico; other conditions and different species of Castilla may be found in the countries to the southward. Moreover, it is scarcely reasonable to expect the interested public to adopt what may appear to be a radical view of Castilla culture without understanding the basis of the current opinion that continuously humid regions are required for the production of rubber.

The Report on the Caoutchouc of Commerce, written by James Collins, and published in 1872 under the auspices of the British Government, remained for many years the most complete and authoritative statement of the subject. It was very frequently quoted by subsequent writers, and has probably done most to establish the idea that continuous humidity is required by Castilla. Collins says:

The species of Castilloa seem to like best and thrive in thick, humid, warm forests. They abound in Nicaragua; and as I have, through the kindness of my friend Dr. Bureau, of Paris, received from M. Paul Lévy, a botanical collector in Nicaragua, a good account of their history there, it will serve to give a correct idea of their habits.

The basin of the Rio San Juan is where the ule tree grows to perfection. This river is the natural vent of the two vast basins of the lakes of Nicaragua and Managua, receiving numerous tributaries, which have all their sources in the innumerable tracts hitherto virgin and unfrequented, and where the trees abound. The ground is very fertile. The district is very unhealthy; it rains for eight or nine months in the year, and the climate is very warm and humid. The trees prefer humid and warm soils, but not marshy, clayey, or gravelly ground, and the presence of these trees is looked upon as an indication of a fertile soil. . . . The ule is often near water-courses, and nearly always on the banks.[a]

CASTILLA IN COSTA RICA.

The most extensive recent publication on Castilla is by Herr Th. F. Koschny, a resident of Costa Rica, whose opinions on the subject of climate appear to be nearly opposite to those stated above. He says:

The safest and most productive rubber plant is the *Castilloa elastica* of Central America. Its tenacity of life and adaptability to soil and climate are seldom exceeded by other trees; the same is also true of the quantity and quality of the rubber.

It requires a humid, warm climate, and with respect to rainfall less depends upon the amount of precipitation than upon the distribution of it. The shorter the dry

[a] Collins's Report on Caoutchouc, p. 14.

season and the more the rain extends over the entire year the better will a locality be adapted for rubber culture; regions with a long, absolutely dry season are unsuitable for this culture. In the valley of San Carlos, Costa Rica, upon the Atlantic slope, it rains occasionally also in the dry season, and even in the two driest months, March and April. The Pacific slope of Central America has, on the contrary, a completely dry season of four months, and two months at the beginning and end with little rain. Both the wild and the planted rubber trees die there at the third tapping at the latest, in case this takes place in the dry season.[a]

If the above statement represents a general fact in Costa Rica it can only be said at present that either the climate, or the rubber trees, or both, are different from those of southern Mexico. In spite of six months of dry weather the rubber trees at La Zacualpa have reached maturity in the open sun, and have survived many and severe tappings, as shown in the accompanying illustrations (Plates I, XII, and XVI).

It may not be without significance that the conditions with which Herr Koschny is most familiar and which he considers favorable for rubber production are not those of continuous humidity, for there is a dry season of two or three months. In eastern Guatemala, an interesting example of the rapidity with which the tropical sun can dry out the vegetation was observed. Our party arrived at Panzos during a heavy rain, and rode the next day toward Senahu over muddy roads through the dripping leaves of a luxuriant tropical growth. Three weeks later the same region was dry and parched, and even the leaves of the undergrowth of the forest were shriveled.

CASTILLA ON THE ISTHMUS OF PANAMA.

The idea that the Castilla sent from the Isthmus of Panama to British India came from a continuously humid district seems not to be justified by the statements of Mr. Cross, who secured seeds and cuttings in the vicinity of Colon. He says:

> The interior of the Darien forests would frighten most people. The undergrowth is composed of boundless thickets of a prickly leaved species of *Bromelia* often 8 to 10 feet high, the ground swarms with millions of ants, and the snakes raise themselves to strike at anyone who approaches.
>
> The Caucho tree grows not in inundated lands or marshes, but in moist, undulating, or flat situations, often by the banks of streamlets and on hillsides and summits where is any loose stone and a little soil. It is adapted for the hottest parts of India, where the temperature does not fall much below 74° F. The tree is of rapid growth, and attains to a great size, and I am convinced that, when cultivated in India, it will answer the most sanguine expectations that may have been formed concerning it. I have been up the Chagres and Gatun rivers. I came out on the railway about 7 miles from Colon. I go back to the same place (the village of Gatun), from which place by the river the India-rubber forests are reached.[b]

The undergrowth of Bromelia indicates a relatively barren, open forest with a severe dry season, and this supposition is strengthened by the allusion to the ants, snakes, "loose stones," and "little soil."

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[a] Beihefte zum Tropenpflanzer, 2:119, 1901.

[b] Trans. Linn. Soc., London, 2d ser., 2:213.

ANALOGY OF THE ASSAM RUBBER TREE.

The fact that the production of rubber may fail under conditions which permit the luxuriant growth of the trees is not new, since it was recorded with reference to the Assam rubber tree as early as 1875, as shown in the following extract:

The production of different kinds of caoutchouc in India continues to engage the attention of the India Office and of this establishment. One fact in connection with it which seems to require very careful consideration has been pointed out by Mr. Mann in his report on the caoutchouc plantations in Assam. It is found that although the *Ficus elastica* will grow with undiminished rapidity and luxuriance in situations remote from the hills, it fails to yield caoutchouc. Mr. Mann concludes that no greater mistake could be made than to start plantations of *Ficus elastica* in any part of Bengal. It appears, therefore, judging from this case, that conditions which may insure the successful growth of caoutchouc-yielding trees may not be sufficient to determine their producing caoutchouc.[a]

THE PARA RUBBER TREE IN HUMID LOCALITIES.

Following the original publication of James Collins, in 1872, writers on rubber have continued to emphasize the humidity of the forests of the Amazon basin.

The Amazon Valley is remarkable for uniformity of temperature and for regular supply of moisture. From June to December is the dry season, and January to May the wet. In the dry season in November there are a few occasional showers, and during the wet season intervals of fine weather. * * * On the banks are *dense* moist forests, with caoutchouc trees interspersed. Dr. Spruce, when at Barra, in December, 1850, found that the rains had set in some weeks previous, and from December 10 to the beginning of the following February only a single day occurred without some rain. In February there were six fair days; in March, the most rainy month, only one; and to April 18 but three days of fine weather. During March the highest temperature was 84¼°; many days it failed to reach as high as 80°. On the Solimoens, or upper Amazon, the sea breeze is not felt, and it is therefore more stagnant and sultry. The whole of the country along its banks is covered with one uniform, lofty, impervious, and humid forest. The soil nowhere sandy, but always either a stiff clay, alluvium, or vegetable mold. The vegetation is very prolific and the atmosphere densely vaporous.[b]

It is difficult to explain why the heavy rains and overflowed rivers have been dwelt upon with so much persistence and the six months of dry weather left quite out of account, particularly since it has been known from the first that the rubber is obtained in the dry season, and Collins himself states that in the wet season the milk is poor in rubber, or "too aqueous to allow of profitable collection."

The late Mr. Jenman, government botanist of British Guiana, has

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[a] Report on the Progress and Condition of the Royal Gardens at Kew during the Year 1875, p. 7.

[b] Collins, J. Report on the Caoutchouc of Commerce, p. 6.

described similarly the conditions which he considered typical for *Hevea spruceana:*

The water lies in shallow pools between the trees, or is spread in sheets, when deeper, over wide spaces of ground, and the surface soil generally, especially where this tree most abounds, is hardly more firm or dense than mud. It will give an idea of its character when I say that I wore a pair of high-laced-up shooting boots, but with the best care in moving about, and stepping mostly on the more solid soil which is usually found in hillocks around the butts of trees, or on the fallen bits of wood which stretch between them, in spite of my care, I was constantly sinking to their tops and over, so that my socks were covered with mud. I am speaking, as I have said, of the wet season of the year, but even in the dry the ground continues in a very moist condition. The land is usually very densely shaded, and in many places, probably in consequence, produces very little undergrowth.

I have taken the occasion to describe rather fully the character of the land, as it is important that persons contemplating the cultivation of this species of Hevea should be well informed as to the conditions which prevail in its native haunts.[a]

It is, of course, to be expected that different species of Hevea will be found to prefer different natural conditions, but the above account, while well showing what even explorers have been expecting to find, has little real bearing in rubber culture in view of the extreme difficulty of carrying on agricultural operations in such a country. Moreover, the average maximum yield obtainable by the destruction of full-grown trees is placed by Mr. Jenman at 1 pound, which was several times greater than what could be secured by tapping.

PRODUCTIVENESS OF PARA RUBBER TREES IN DRY SITUATION.

A Para rubber tree in the Botanic Garden at Penang, on the Malay Peninsula, is noteworthy as having a reliable record of six tappings in five years, with a total of 15 pounds and 10 ounces of rubber. The tree was set out in 1886, and was about eleven years old before it was tapped. Some of the incidents, as related in the following paragraph, are not without interest:

No particular attention was paid to these trees at the time more than to the many other economic and ornamental plants that were planted in this garden that year, then in course of foundation, and it so happened that two were planted side by side on poor gravelly soil on sloping ground, which, by the subsequent cutting of a new road alongside them some years later, converted the site on which they are growing into what is virtually a dry bank. When, some ten years after these trees were planted, the questions of the best method of extracting and coagulating rubber, and the probable yield to be expected, commenced to interest the planting community, this tree as being the largest in the garden, was selected for experiments, which have been continued from time to time and the result recorded in the annual reports. There is nothing remarkable about this tree except that, as planters have often remarked, it is remarkably small for its age, but that is not surprising, considering the nature of the soil and the situation in which it is growing.[b]

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[a] Timehri, 2:14, 1883.

[b] Agricultural Bulletin of the Straits and Federated Malay States, 1:385, August, 1902.

Notwithstanding the apparently unfavorable conditions and the rather severe treatment to which it has been subjected, the tree is described as in healthy condition, with all its wounds healed. It has a height of about 55 feet and a girth of 66 inches, having increased from 36 inches in 1897, when tapping was commenced.

THE TRUE CLIMATE OF HEVEA.

The results of the writer's observations on Castilla were so much at variance with prevalent opinions concerning climatic requirements that the possibility of a similar error having been made with reference to Hevea naturally suggested itself, and various indications like the preceding were found in the literature of the subject suggesting that this might prove to be the case. Shortly afterwards there appeared the following quotation from a paper written by Mr. H. A. Wickham, who made the original introduction of Hevea seeds from Brazil to British India, and whose testimony is so direct and conclusive that we need wonder only that so important a point should have been so long overlooked:

> But as all the stock of plants or seed available for the planting and cultivation of this tree in the Eastern Tropics are and will be derived from direct lineal descendants of some or other of those 7,000-odd originally introduced by me at the instance of the government of India in 1876–77, it may be well if it be recollected that their exact place of origin was in 3° of south latitude, and to remember their natural conditions there. This the more so since a very general error seems to have obtained that swampy or wet lands are the fitting locality for the Hevea. This would seem to have arisen in that the "explorer" of a few years' experience would have some of these trees pointed out to him (naturally in answer to inquiries) growing scattered along in the wet margins in going up the lower Amazon or tributaries, whereas the true forests of the Para Indian rubber trees lie back on the highlands, and those commonly seen by the inquiring traveler are but ill-grown trees which have sprung up from seeds brought down by freshets from the interior.
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> As a matter of fact, the whole of the Hevea which I procured for the government of India were the produce of large grown trees in the forest covering the broad plateaus dividing the Tapajos from the Madeira River. The soil of these well-drained, wide-extending forest-covered table-lands is stiff, not remarkably rich, but deep and uniform in character. The Hevea found growing in these unbroken forests rivals all but the largest of the trees therein, attaining to a circumference of 10 feet to 12 feet in the bole. These forest plains having all the character of wide-spread table-lands occupy the space betwixt the great arterial river systems of the Amazon, and present an escarped face, which follows at greater or less distance and abuts steeply on the igapo or bagas, i. e., the marginal river plains subject to inundation by the annual rise of the great river. So thorough is the drainage of this highland that the people who annually penetrate into these forests for the season's working of the rubber have to utilize certain lianas (water-bearing vines) for their water supply, since none is to be obtained by surface-well sinking, in spite of the heavy rainfall during a great part of the year. [a]

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[a] Agricultural Bulletin of the Straits and Federated Malay States, September, 1902, pp. 476–477.

THE CULTURE OF CASTILLA.

In attempting to plan a rational culture for Castilla it will be worse than useless to insist upon all or any of the cultural measures which have been found desirable with coffee, cacao, or other tropical crops. Castilla is not cultivated for the leaves like coca, for the flowers like cloves, for the fruits like oranges, nor for the seeds like coffee. The increase of the size of the trunk and of the amount of milk contained in its inner bark are the objects of cultural solicitude.

SHADE IN THE CULTURE OF CASTILLA.

SHADE NOT A NECESSITY.

Much of the preceding discussion of the habits of Castilla and of the climatic conditions suitable to its culture may also serve as preliminary to the consideration of the question whether plantations of Castilla require the shade of larger trees or may be exposed to full sunlight. The argument that Castilla always grows in shaded locations in nature is by no means conclusive, since it is well known that many forest trees thrive better when they have the opportunity of standing alone and are free from the close competition for food and sunlight implied by forest conditions. It is also certain that Castilla is not only able to obtain an existence in the open, but that it makes much more rapid growth quite without shade than it does in the forest. If the problem were merely to secure the quick growth of Castilla, there would be no hesitation between these two methods of planting; but there are many stages between dense forest and clean culture, and the question may well be raised whether the conditions most favorable for rubber production are not to be found in some of these. Advocates of both extremes and all intermediate conditions are not lacking, so that the question of shade with Castilla bids fair to become as complicated and as extensively debated as with coffee and cacao. Moreover, as with those crops, it may be found to have no general solution, but to depend upon local conditions of soil and climate.

That rubber can be grown under forest conditions there can be no doubt, since all the natural supplies are to be credited to this method of production, but the desirability of forest planting does not necessarily follow, since it is equally certain that under the deep shade the trees grow with an extreme slowness, which would exhaust the patience of any investor. Moreover, as previously shown, it may well be doubted whether a plantation of Castilla would ever grow to normal maturity in the undisturbed forest; the indications are that only those trees survive which are able to profit by accidents to their larger neighbors and thus receive more sunlight than usually reaches the undergrowth of a dense tropical forest. In other words, regular forest planting does not mean the placing of Castilla under conditions most favorable to its growth in nature; these are more nearly attained when the forest is thinned out or partly cut away.

Koschny, who distinguishes four kinds of Castilla in Costa Rica, says that the "hule blanco," or white Castilla, is the only one adapted for cultivation, and that this is never found in the deep forest, but in more open places, where the foliage has access to the sunlight.

Experiments with forest planting were studied in eastern Guatemala and in southern Mexico, and in both instances the young trees were at an obvious disadvantage in comparison with others planted at the same time in more open situations. Plates XIII and XIV will serve to illustrate the difference, for although the tree shown in the latter had suffered the loss of its terminal bud the number of leaves and the amount of new growth it had made was not below the average. Many individuals had hardly grown at all in six months and many had died. On the other hand, it should be explained that the trees, like that shown in Plate XIII, while they had no shade overhead were not exposed to the extent which might be implied by the term "open culture," since they stood in a clearing only a few acres in extent. The neighboring forest gave shade in the morning and afternoon, and the atmosphere was undoubtedly kept far more humid throughout the day than would be the case in a large tract of unshaded land baked by the tropical sun. They were also undoubtedly assisted by a mulch of dead leaves and brush. Trees 12 feet high were said to be only 1 year old.

It would seem, then, that one of the extreme suggestions—the planting of rubber in the undisturbed forest—is clearly inadvisable and may be dismissed from further consideration. The other extreme—clean culture—is not so readily condemned as impracticable, since observations in southern Mexico establish the fact that even single trees, standing in the open sun and with little other vegetation near them, are not only able to survive six months of dry weather, but actually remain more leafy at the end of the dry season and thus appear to suffer less from drought than those on land covered with weeds and bushes. The reason for this apparent anomaly may not be difficult to conjecture, since it is plain that a tree standing in cleared ground has a monopoly of all the moisture which rises in the soil, and may thus have a distinct advantage over one obliged to share a similar supply of water with a tangled mass of other plants which expose to the atmosphere a total leaf surface many times that of the young rubber tree. Moreover, it is also clear that the water required to supply the needs of this large amount of vegetation would greatly exceed that which escaped from the exposed surface of the soil. It is even doubtful whether a covering of low vegetation greatly checks the evaporation from the soil; it may be as great or greater than where the surface of exposed soil is loosened by stirring and thus forms a layer which hinders the access of dry air and is a nonconductor of heat. In previous discussions of shade in the culture of Castilla this distinction between open culture and clean culture seems to have been overlooked, and the question of shade has continued to be confused with that of water supply. The statements of various writers that the leaves are unable to withstand exposure to the full sun because of their delicate texture are quite erroneous. The tree needs sunlight, and is benefited by it as long as the water supply is sufficient, but when this becomes deficient the leaves shrivel. The light is no brighter and the temperature no higher in the dry season, which in Mexico occurs in the winter months; but the dry atmosphere demands more water, while the soil supplies less.

The rapidity with which dry atmosphere takes water from a plant may be judged by the promptness with which the leaves of a broken branch wilt and shrivel, and this happens very promptly with Castilla. Many plants have developed no expedients for resisting evaporation and are accordingly confined to continuously humid regions, but Castilla, as has already been seen, is adapted in several ways for resisting drought. The leaves themselves are, it is true, of rather loose texture and have only the slight assistance of the hairs of the lower surface as a protection against excessive transpiration. The leaves suffer when they are obliged to part with more water than they can obtain, and their falling off is then an advantage because it decreases the demand for water. Thus, although Castilla is not a desert plant, the falling of its leaves in the dry season is the same physiological phenomenon which appears so conspicuously in deserts, viz, the loss of the leaves as a protection against drought. Many desert plants such as Parkinsonia, Fouquieria, Peireskia, and species of Euphorbia put out leaves for the wet season only, while most of the Cactaceæ and many Euphorbias have discarded leaves entirely and expose as little surface as possible to the air.

This digression may help to make it apparent that the planter who desires to give intelligent consideration to the agricultural question of shade should dismiss the notion that the rubber tree derives a direct advantage from standing in the shadow of another tree; on the contrary, it is probable that interference with the sunlight is always a direct disadvantage. Shade, if used at all, is to be applied and justified on the ground that it will preserve the moisture of the soil or of the atmosphere or serve some other cultural purpose. By conserving the soil moisture, clean culture may produce some of the desirable effects commonly ascribed to shade. Open culture may be, and probably is, less advisable than either clean culture or a moderate shade culture.

Open culture with relatively little cleaning at first would be more practicable if the weeds and undergrowth cut down in the dry season could be left spread over the ground. This would do more to conserve the moisture of the soil than the same vegetation alive, but the danger of fire will in most localities forbid the use of this method of culture.

If the present question could be settled by deciding whether or not Castilla needs to be protected from the sun, it would be easy to establish the negative view; but with shade recognized as a means of influencing natural conditions of soil or climate it becomes evident that each planter will need to use his best judgment in determining what local conditions require. In Costa Rica Koschny advises the thinning of the forest by the removal of two or three trees out of every five. At La Zacualpa more are cut out (Pl. XV). Some of the planters on the Isthmus of Tehuantepec practice clean culture. No general principles will determine which is best, because no one method is applicable everywhere.

RELATIVE COST OF SHADE CULTURE.

It must be remembered, in addition, that the planter finds himself compelled to decide not what will be the best for the rubber trees, but what is the best he can afford to do for them. Is it, for example, good policy to use labor and capital in keeping a tract of planted land clean, or will more be gained ultimately if one contents himself with somewhat slower growth and improves the opportunity of planting additional tracts with trees that can also be growing? Careful comparative experiments might be necessary for an answer, and this might differ for different localities.

EFFECT OF SHADE ON FORM OF TREE.

There are great and persistent differences of shape or "habit" among trees. The Lombardy poplar and the weeping willow are not distant relatives. It is a general fact, however, that forest trees are taller and more slender than those of the same species grown in the open. The low spreading habit, which is desired and encouraged among fruit trees, is not desirable in rubber-producing species, where a large expanse of trunk is needed to supply the milk and to give opportunity for tapping without the necessity of wounding the same place too often. Castilla trees growing alone in the open often send out permanent branches 8 or 10 feet from the ground, while those in the forest may have from 20 to 40 feet of smooth trunk before the permanent branches are reached. Open-grown trees may have large spreading branches, while in the forest or under close planting the main axis of the tree continues to grow upward and the lateral branches are relatively small.

The problems of rubber culture may prove in this respect to be directly opposite to those of coffee, where the formation of much wood in proportion to leafage is a sign of unfavorable conditions or of bad plantation management. It does not follow, however, as some have seemed to suppose, that forest shade is necessary to grow long-trunked trees. In coffee culture it is plain that the most wood is formed not by shade culture, but by planting close in the open, and the older-planted trees of Castilla at La Zacualpa, if not as slender and as smooth-trunked as those of the forest, are certainly tall and slender enough to furnish ample evidence that open culture does not cause a low, spreading growth, if the trees stand close enough together (Pl. I). The Zacualpa experiment is of further significance in this connection, because it shows that a harmful degree of crowding was by no means reached. In numerous instances where from three to five (Pl. XII) trees grew in a cluster their trunks were each equal in size to those of many of their neighbors which stood alone.[a]

Coffee trees which stand too close together lose the use of their lower branches, which become interlaced and shade one another, and ultimately only the top of each tree continues to grow and produce fruit. The planter must choose a middle course between the injury of his bearing trees by crowding and the waste of capital and labor in keeping clean unused land between trees planted too far apart. With the rubber tree the seed is a consideration entirely secondary to the growth of the trunk. In comparison with coffee it may be said that the crowding of rubber trees is desirable, and that it finds its limit, not in the discouragement of lateral branches, nor even in the lessening of the size of the individual trees, but in the decrease in the amount of rubber which can be produced on a given area of land.

SHADE AND RUBBER PRODUCTION.

The general question of shade can not, however, be treated as closed until its influence on the yield of rubber has been tested by careful experiment. From the facts given on previous pages it appears very improbable that less rubber will be formed in the open than under shade; the difficulty, if any, is likely to arise in connection with the extraction of the rubber. The desirability of tall trunks to afford a large tapping surface has been noted already, but there may be other disturbing factors. The pressure of the liquids inside a tall columnar trunk may be greater than if it were thicker and shorter, so that more milk would be forced out on tapping. The bark of trees more exposed to wind and sunlight becomes thicker and there may be differences in texture which would affect the flow of milk. The air is much drier outside than inside the forest, and this might soon impede the flow of milk, though this suggestion seems to be negatived by the fact that

[a] Planting in clusters might be advisable on some accounts, since the trees would better shade their trunks and the ground under them, but the difficulty of properly tapping such trees would seem to exclude this method of culture.

milk flows more freely from wild Castilla on the dry Pacific slope of Mexico and Central America than in the more humid districts of the Atlantic side.

A recent writer on the shade question claims to have discovered that, while planting under partial shade hinders the growth of the trees, it greatly increases the yield of rubber. The managing director of a rubber plantation operating in Mexico writes as follows to the India Rubber World:

> We are planting in the partial shade; a great many planters are planting in open sunlight. My honest opinion is that every one who has planted in open sunlight will get a tree 50 per cent larger in five or six years than we in the partial shade. On the other hand, we will get from 60 to 75 per cent more rubber from a small tree than they do from a large one. About three months' careful study was made of this proposition; the trees were tapped both in the shade, partial shade, and open sunlight, and the results carefully tabulated by a committee of which I was not a member.

It is easy, however, to understand how such an opinion could be formed if the experiments in tapping were made at a time when the trees planted in the open were drier than those in the shade, and such a difference would be especially pronounced in young trees. This observer did not find that the milk was richer in rubber in the shade, but merely that at a certain time more milk flowed from the shaded tree than from the unshaded tree. This would not, however, be an argument for shade planting unless it were shown that the unshaded trees would not at any other time yield more milk. It is quite probable that shaded and unshaded trees might need to be tapped at different times to secure a maximum flow, or it might be found that unshaded trees could be tapped with impunity more frequently than the others, and thus afford a larger annual yield. The flow of milk does not depend so much upon the amount in the tree as upon the pressure existing at the time the tree is tapped. The indications are that pressure attains its greatest intensity in trees which are exposed for a part of the time to a relatively dry atmosphere and which are accustomed, as it were, to pump water rapidly to supply the leaves. Such trees may, on the contrary, yield no milk at all when the water supply is deficient. It may be expected, therefore, that open culture will require much more careful attention to the time of tapping. This may prove a disadvantage if it requires all the trees of a large plantation to be tapped on the same day or in the same week, but this is not likely. On the other hand, tapping at the right time would mean the drawing of a larger amount of milk from a smaller cut, a saving of labor, and a lessening of injury to the trees.

The above considerations make it easy to understand also that writers acquainted with humid districts commonly refer to the rubber harvest as occurring in the dry season, while in the drier regions, as in Soconusco, the beginning of the rainy season is the recognized time, when the tree's demand for water is largest and the internal pressure highest.

LEGUMINOUS SHADE TREES TO BE PREFERRED.

Where the policy of thinning out the forest is followed the question arises as to which trees are to be left and which cut down. A study of coffee and cacao culture has revealed the probability that much of the benefit ascribed to shade is due in reality to the nitrogen furnished by the bacteria of the root tubercles of the leguminous trees which are preferred in all countries where the shade culture of coffee has become popular. If shade trees are to be planted with rubber, they must be different from the species of Inga which are preferred for coffee shade in Mexico and Central America, for the reason that Castilla grows faster than Inga. Some leguminous trees, however, grow with great rapidity and may be able to outstrip the rubber. No comparative experiments seem to have been made. If, as suggested above, shade trees are more useful as windbreaks than for the shadow they cast on the rubber, the planting of fruit trees like the mango or other useful species in rows or hedges would be preferable to scattering them amongst the rubber.

DISTANCE BETWEEN TREES.

As yet there have been no experiments yielding any definite information on the above point, but the recent trend of opinion among planters seems to be distinctly in the direction of closer planting. There has been a gradual decline from 20 feet and upward between trees to 12 feet and under.

The questions of shade and of distance between trees are closely related and need to be considered together because several of the arguments for shade can be met, wholly or partially, by close planting. The first of these is that of the greater expense incidental to open culture. The frequency with which the land requires to be cleaned and the period of years during which it would be necessary to continue such cleaning depends largely upon the amount of overhead shade present to discourage the undergrowth. Some planters on the Isthmus of Tehuantepec are evidently taking advantage of this fact and are setting close, with the intention of removing alternate trees before they are large enough to injure their neighbors by crowding; and it is expected that if they are "tapped to death" they can be made to yield enough rubber to more than cover the expense of planting. At least there seems to be no reason why, if the land is to be cleared, it should not be made to produce as much rubber as possible instead of being planted with useless trees for a purpose which can be attained quite as fully by setting the rubber trees closer together.

There is danger, however, that any suggestion which promises earlier returns from rubber culture will be overdone. The rubber of very young trees is of low grade and expensive to collect; also it would be very poor policy to risk permanent injury from weak spindling growth, which overcrowding would undoubtedly cause. More is likely to be lost than gained by trees standing at less than 8 feet for even a few years. Better than uniform close planting would be to set the north and south rows farther apart than the trees in the rows. With a given number of trees this would secure the maximum of shade on the ground, because the morning and afternoon sun would not shine down the rows. The cleaning of the land or the cultivation of a catch crop or a shade crop between the rows would also be facilitated. The distances would depend on the size which the Castilla trees were expected to attain in any given locality, the rows from 12 to 20 feet apart, the trees from 8 to 12 feet in the rows being fair average estimates.

METHODS OF CLEARING LAND FOR RUBBER PLANTING.

The question of shade is also involved with that of the method of clearing the land. It is an almost universal custom in tropical countries to clear land by burning the dried forest growth which has been cut down. In fact, the primitive agriculture of the natives of tropical regions could scarcely be conducted on any other basis. There is much loss of fertility by the destruction of vegetable matter and humus, but the amount of labor required to thoroughly clear a piece of forest land in the Tropics is prohibitively great. The fire not only removes the tangled mass of brush, but it performs an even more useful service in killing the stumps and roots which would otherwise reoccupy the land with new growth in a few weeks, and would remain indefinitely to dispute possession with anything which might be planted. To grow a herbaceous crop on unburned land under such conditions would be extremely difficult, but a tree culture is much more feasible, though whether the method of partial clearing is to be generally advised is not so certain. The gain, if any, is more likely to be found in the sustained fertility of the soil than in any saving of labor in clearing and cleaning the land; for although there may be a saving at first which will permit an enterprise to reach a paying basis sooner, yet there is in prospect a long and expensive struggle with the persistent natural vegetation rooted in the soil. Moreover, it should be recognized that the conditions under which a plantation is set out in a partially cleared forest are of necessity only temporary. Many of the forest trees will not long survive the unwonted exposure to greater dryness and heat and to the attacks of parasites. The thinning of the forest greatly increases the force of the wind against the remaining tall trees, and in falling these will injure the rubber trees and will often require to be cut away not merely at one point, but at several points. Whatever the merits of the case from the standpoint of the stockholder, the plantation manager of the future is very likely to wish that his predecessors had adopted clean culture. The overhead shade which discourages the undergrowth will also discourage the rubber, and the decrease of such shade will increase the competition of the undergrowth with the rubber. The ideal of rubber culture does not require a roof of shade over the rubber trees nor a dense growth of bushes and vines under them. The roof should be of Castilla foliage, and the ground should be covered by a mulch of dead leaves and branches, which enrich the soil and assist in the retention of moisture.

CLEAN CULTURE WITH FOREST PROTECTION.

If, then, the requirements met by close planting be eliminated from the shade question there remains little beyond the fact that in districts in which the dry season is unduly long it may be unwise to shorten the period of growth by cultural methods which increase the daily exposure to too dry an atmosphere, as there can be no doubt that the clearing of large tracts of land will mean warmer and relatively drier air, and that the dryness of the air near the ground will be further increased by the wind, against which the forest will no longer afford protection. It might accordingly be good policy on large estates not to clear continuous tracts for planting, but to leave belts of forest to break the wind and keep the atmosphere moist. This method would be particularly convenient where the land is to be cleared by burning, since in a tropical forest the trees often grow with their branches interlaced or are bound together by large climbing vines or lianas, so that it is often much easier to clear an entire strip of forest than to leave individual trees standing at anything like regular intervals.

METHODS OF HANDLING CASTILLA SEEDS.

The thin-skinned seeds of Castilla, like those of so many other tropical plants, are adapted only for germinating on the moist soil of the forest. Instead of having a hardened shell for protection, there has developed only a fleshy pulp, which in nature helps them to remain moist until the rains begin. They are able to resist exposure to even a moderately dry atmosphere for only two or three weeks, and if packed together in any quantity they spoil even more promptly. The perishability of the seeds has been a considerable obstacle in the planting of Castilla, and especially in its introduction into foreign countries. The first shipment of 7,000 seeds secured by the government of British India from Panama in 1875 was a total loss, and the introduction was made by means of a few cuttings, carried around by way of England. Later the Kew Botanical Gardens sent rooted cuttings also to Liberia and to the Kamerun River settlements in West Africa, to Zanzibar, Mauritius, Java, and Singapore, as well as to Jamaica and Granada in the West Indies.[a] In 1880 the largest of the Ceylon trees was 17 inches

[a] W. Thistleton Dyer, Trans. Linnæan Soc., London, 2d ser., 2:214, 1885.

in circumference a yard from the ground, and in 1881 they flowered for the first time. The first flowers were all staminate, but a few seeds were produced in 1882, and these and their successors have furnished the basis of the experiments with Castilla in the East Indies. The relatively unfavorable results may be due, at least in part, to the fact that the Panama tree is different from that of Mexico and Guatemala, which was sent to the East Indies only in recent years, after better methods of packing the seeds had been learned.

The preservation of the seeds depends upon their being kept moist enough to remain alive and at the same time dry enough to discourage germination. Some advise washing the seeds; others leave the pulp adhering, but the latter course has the disadvantage of encouraging the growth of molds and bacteria, which readily penetrate the thin outer membranes and attack the embryo itself. Several packing materials, such as leaf mold, sand, and sawdust have been suggested, but the best is probably powdered charcoal, which does not decompose nor harbor organisms.

The following statements from some who have experimented with shipment of Castilla seeds may be of suggestive interest:

> In Trinidad they are gathered when fully mature, washed, and slightly dried in the shade. They are then shipped in a sort of humus composed of fibers of rotten cocoanut husks and a little earth. This mixture must be somewhat moist. The seeds soon germinate in it and so remain for several weeks. Sowing must be done with great care on account of the long sprouts.
>
> I also collected the mature seeds and washed them thoroughly, so that no trace of the fleshy red pulp remained on them. Then they were dried in the shade from twenty-four to forty-eight hours, and then mixed with sawdust and packed in small tin boxes 10 centimeters (4 inches) square and 3 centimeters (1.2 inches) deep. I dropped a few drops of water on the sawdust before closing the box. With this packing the seeds were sent to Berlin, and from there forwarded to Kamerun and East Africa, and 50 per cent of them were on arrival still good and in condition to germinate.[a]

A shipment of 2,000 Castilla seeds sent from Paris to Peradeniya, Ceylon, packed in leaf mold in four tin boxes, was opened in six weeks, to find 37 per cent still alive and the remainder destroyed by molds and bacteria. This made it evident that leaf mold was not a desirable medium and sterilized sand was suggested instead.[b]

> The seeds were carefully cleaned of all pulp, and then dried slightly in the shade and packed in shallow tins with powdered charcoal slightly damp. By this method they commence to germinate in the tins. Care must be taken that the seeds do not touch each other, for if too many are packed together it will cause heating and the loss of the whole.[c]

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[a] Dr. Paul Preuss, Expedition nach Central- und Sud-Amerika, 1901, p. 383.

[b] Agric. Bul., Straits Settlements, 1:580. Dec., 1902.

[c] Letter from Mr. W. S. Todd, Amherst, Lower Burma, to Mr. Edgar Brown, in charge of Seed Investigations, U. S. Department of Agriculture.

It was learned also that rubber seeds packed in charcoal and shipped from one of the plantations of the Isthmus of Tehuantepec to the East Indies had arrived in good condition after a journey of forty-five days.

SEED BEDS AND NURSERIES.

Whether it is better to plant the seeds where the trees are to stand or to sow them in nurseries from which the seedlings are to be subsequently transplanted is one of the many questions on which opinions differ, though the latter method commands a large majority of preferences. Of 26 plantations from which reports have recently been published by the India Rubber World, only 3 plant "at the stake" exclusively.

At La Zacualpa Mr. Harrison has tried planting in the permanent location, but finds that the very young seedlings are liable to be destroyed by insects and that they do not grow as well in partial shade as in the full sun. But instead of leaving the plants in the nursery for a year, transplanting begins when they are six weeks old, or when the plants are from 10 to 12 inches high, and continues to near the end of the rains, no nurseries being carried over the dry season. These are considerable deviations from the methods which have been described in previous publications on rubber culture, most of which advocate the shading of the nurseries and the postponement of transplanting till the seedlings are a year old. It is claimed at La Zacualpa that the small trees suffer less from transplanting and that they are larger at the end of two years than if they had remained in the nursery for a year.

The seed beds at La Zacualpa are made each year in a new place convenient of access to the tracts which are to be planted. While the nurseries are not shaded overhead, they are generally located in clearings in the forest, where they have considerable protection against dry wind. The drying out of the soil would doubtless be fatal to young seedlings, but if the soil and air are sufficiently moist the sun does not harm them.

The land used for nurseries is cleaned by burning, though this is not the case at La Zacualpa with the plantation proper. When older seedlings are transplanted it is customary, as with coffee, to cut the taproot down to 5 or 6 inches, rather than to plant it bruised or bent. If the soil is loose and fertile the seedlings are set in holes made with a pointed stake; elsewhere it is better to dig holes, as with coffee. Castilla is not a delicate plant, and will endure any reasonable treatment. The worst danger seems to be that with long-continued rain and deficient drainage the young plants will rot off, or they may be killed by drought if planted too near the end of the rainy season. For those which have not become sufficiently established before the coming of dry weather artificial shade may be provided. At La Zacualpa one of the tracts which represented an experiment in open planting had each young seedling covered with a hood made of leaves of the manaca palm (Attalea).

PROPAGATION OF CASTILLA FROM CUTTINGS.

Under favorable conditions Castilla roots readily from cuttings. Between Pueblo Nuevo and Huitzla, along the road from Tapachula to La Zacualpa, there is a row of several trees planted as fence stakes, but at present flourishing in an entirely normal manner. That trees raised from cuttings are not stunted or otherwise abnormal is also shown by many other instances in the neighborhood of Tapachula. Indeed, this was the origin of the largest tree observed (Pl. IX). It measured 7 feet in circumference about 5 feet from the ground. It was about 33 feet to the first limb and the total height was estimated at 80 feet. The owners claim that it has yielded 6 pounds of rubber. It had apparently not been tapped as persistently as trees at La Zacualpa, perhaps because protected from "huleros" by standing close to a house. Milk flowed freely from a knife cut, and appeared to be rich in rubber. Natives claimed that an arroba (about 25 pounds) of rubber could be obtained from such a tree by the methods used by them in the forest. This tree was further notable in that it had apparently grown up in the open and without near neighbors.

The propagation of Castilla from cuttings has already been mentioned as the quickest method of bringing about the selective improvement of Castilla. It is not known that any plantations have been stocked with cuttings, presumably because in localities where they could have been obtained seedlings could be had more readily and in larger numbers. Indeed, wood suitable for cuttings does not exist in very large quantities even in a well-grown tree, because the false or temporary branches can not be used for this purpose. Like the lateral branches of some of the coniferous trees, they are unable to give rise to normal terminal buds, so that even if false branches could be rooted they would not produce normal trees. The failure of such experiments has been reported from British India.

Planters resident in regions in which wild rubber trees exist could try a useful experiment by planting in rows cuttings taken from different wild trees known to be above or below the average in productiveness. This would enable them to determine whether the differences of yield were due to the external conditions or to causes inherent in the trees themselves. The probability is that very appreciable individual differences of productiveness will be found, and that a distinct advantage can be secured by using cuttings of such trees for propagating purposes.

The fact that stakes 5 or 6 feet long and 2 or 3 inches through take root and grow when simply set in the ground shows that propagation from cuttings will be easy. The larger the cutting the more promptly the tree may be expected to reach maturity. Probably also the mature wood will root better than the succulent young shoots, as with many other tropical trees.

CASTILLA AS A SHADE TREE.

The substitution of Castilla or other rubber-producing species for the unproductive shade trees commonly grown with coffee, cacao, and other tropical crops has been persistently advocated ever since the subject of rubber culture began to receive popular attention. The advantage of such a plan appears so obvious and certain that many experienced tropical agriculturists have been betrayed into direct and even emphatic statements for which the facts have unfortunately failed to provide a warrant. Indeed, it might be said that this phase of rubber culture affords the best illustration of the lack of definite knowledge which hinders practical progress.

In the first place, the shading of coffee and cacao is a subject upon which there is much popular misconception and difference of opinion, the planters of some regions shading heavily and those of others not at all, and explaining their methods by the most contradictory reasons.[a] It seems, however, that there is not the slightest reason to believe that either coffee or cacao is injured by standing in the sunlight or is in any way advantaged by having its leaves shaded, though in countries subject to a long dry season the shading of the ground and the retention of atmospheric humidity may be beneficial cultural measures. That Castilla is in no way adapted for serving these purposes is apparent as soon as it is known that wherever there is a distinct dry season the leaves fall off at exactly the time when they are most needed. It is true that they would still be of some service in covering the earth, but, on the other hand, the loss of the accustomed shade renders the atmosphere much drier and may be a distinct injury to the coffee.

Not only does Castilla thus lack the first qualification of a shade tree, but its cultural requirements and those of coffee are entirely at variance. Castilla seems likely to produce rubber in paying quantities only at low elevations, while the profitable cultivation of coffee is seldom considered possible at an altitude of less than 1,000 feet. In elevated continuously humid coffee districts the rubber trees will hold their leaves but will produce little or no rubber, while to choose an intermediate situation would be more likely to insure two failures than to double the chances of success.

It is reported that an extensive experiment is being made in Salvador with Castilla as a shade tree for Arabian coffee.[b] The altitude is

[a] These have been discussed in some detail in Bulletin No. 25, Division of Botany, U. S. Department of Agriculture, entitled "Shade in Coffee Culture."

[b] Der Tropenpflanzer, 6:542, October, 1902.

not stated, but since the Castilla at two years from planting is described as only 3 to 8 feet high the conditions can not be regarded as favorable.

The suggestion of Castilla for cacao shade is somewhat more rational, since both trees are natives of the same regions of low elevation. As noted elsewhere, rubber was first planted at Tapachula as shade for cacao, but the experiment did not appear promising from the standpoint of the cacao, and was abandoned. Some of the cacao trees still remain, but they have never been vigorous and produce very little. Other causes of failure may, of course, exist, but it seems certain that the close planting which is now favored would make a rubber plantation a very poor place for cacao, and there is every reason to believe that, while cacao may not be benefited by shade, it may be seriously injured by sudden exposure to the sun, as happens when the leaves of Castilla fall in the dry season.

A further difficulty in the use of Castilla as shade is that, in order to permit anything to grow under it, wide planting is necessary, and this usually means a spreading low growth for the rubber trees, generally considered undesirable, because it makes the extraction of rubber difficult if it does not actually decrease the yield. In German New Guinea, for example, Castilla has been planted 33 feet apart in alternation with cocoa palms as shade for Liberian coffee.[a] It would seem that all three trees must suffer under this arrangement, but it will be interesting to learn which is injured least.

Vanilla culture under Castilla has also been suggested and may be worthy of consideration, since it is held that a period of dryness and exposure to the sun is necessary for the proper ripening of the pods. To successfully combine two or three cultures is, however, a difficult matter, even when all are well known, but the supposed practicability of such combinations has rested on ignorance of important details.

Several years ago the culture of Castilla received a considerable impetus from the recommendation of Dr. Daniel Morris, now imperial commissioner of agriculture for the British West Indies, that Castilla be used as shade for coffee and cacao in British Honduras, and an estimated return was made of $5 per tree in eight or ten years or $125 per acre, to be repeated at intervals of five years.

According to Dr. Carl Sapper, a German scientist very familiar with Central America, this advice has been followed with disastrous results. He says:

> In fact, the developments thus far in the field of Castilloa culture show on the average very little in the way of favorable results. Particularly does it seem to have failed completely when it has been combined with other tree cultures in order to lessen the expenses of opening rubber plantations. Thus, on the advice of the well-known English botanist, D. Morris (then in Jamaica), rubber trees were planted for shade in the coffee plantation San Felipe, near El Cayo, in British Honduras, and the result

[a] Der Tropenpflanzer, 7:21, January, 1903.

was that these shade trees ruined the coffee, but did not on the other hand themselves develop normally because they were planted too close. In other places, as in Tabasco, in the Department of Pichucalco, in Chiapas, and in Chamá (Department of Alta Verapaz, Guatemala) rubber trees were used for shade on cacao plantations; but the cacao planters tell me that ule trees impair the growth of the cacao and do further damage through the falling of the leaves, so that they would much prefer to be rid of these shade trees if that were practicable. In other instances, where the ule was planted by itself, too close an arrangement was chosen, so that the trees were impeded in development and are still after twelve years of existence mere tall, slender, unproductive poles, as at Los Amates, Department Izabal, Guatemala, with only four yards of space.[a]

It seems, however, that Dr. Morris has a favorable report regarding Castilla as a shade tree for cacao, both in British Honduras and in the West Indies, and his former advice was repeated before the agricultural conference of the West Indies in 1901. He said:

In 1883 I published an account of the Castilloa rubber tree of British Honduras and the manner of extracting and curing the rubber. At that time I recommended that these trees might be used as shade trees for cacao. A trial was made sixteen years ago, on a cacao plantation on the Settee River, and I learn from a letter from the superintendent of the botanic garden at Belize, dated November 8 last, that the rubber trees have answered admirably for this purpose. He writes: "At Kendal on the Settee River the cacao plantations are thriving well. * * * Castilloa was planted for shade; these are also in good condition; * * * there is not a better tree for that purpose." I am glad to find that similar results are reported from Trinidad and Tobago.[b]

The report from Tobago, to which Dr. Morris refers, is particularly enthusiastic and seems to indicate that under the conditions existing on that island the planting of Castilla with cacao may not be inadvisable:

I find that cacao bears very well under the shade of Castilloa. Nine years ago I planted an acre of rubber and cacao together—the rubbers at 24 feet apart, and the cacao 12 feet—and so far as I have noticed there is very little, if any, difference in the bearing of these cacao trees and those under the shade of the *Bois immortelle.* On finding this, I planted last year 15 acres in the same manner, and there is every reason to expect that in another eight or nine years they will give a gross return of about 50 pounds per acre. Coffee also bears well under *Castilloa.*[c]

The difference between Castilla and leguminous shade trees may become apparent in later years as the nitrogenous constituents of the soil become exhausted. As explained elsewhere, the question is not whether Castilla can be used as a shade tree, but whether it will be productive where it is of use in this capacity.

EXTRACTION OF THE LATEX OF CASTILLA.

Scarcely second in practical importance to a solution of cultural problems is the attainment of satisfactory methods of tapping. The

[a] Der Tropenpflanzer.

[b] West Indian Bulletin, 2:113, 1901.

[c] West Indian Bulletin, 2:111, 1901.

object is not merely to avoid the destruction of the trees, but to learn how the maximum quantity of rubber may be secured with the least injury to future productiveness. The planter needs to know how soon young rubber trees should be tapped, how the incisions should be made, how close together, how large, and in what direction; how often tapping may be repeated, at what seasons, and much more.

The first notion of the visitor from the United States is that it will be a very simple matter to improve on the rude gashes made by the machete of the rubber gatherer, but this has not proved to be easy. The rubber milk is not the sap of the tree and can not be drawn out by boring holes in the trunk, as is done with the sugar maple. The milk does not pervade the tissues of the tree, but is contained in delicate tubes running lengthwise in the inner layers of the bark, and to secure milk in any quantity it is necessary to open many of these tubes by wounding the bark. The rubber is formed in floating globules inside the tubes and can not pass through their walls, so that even a suction apparatus would not bring it out unless the tubes were cut.

PRIMITIVE METHODS OF TAPPING.

The method by which the natives of Soconusco have been accustomed to extract the milk is shown in Plate XVI. The ulero makes with his machete diagonal lines of gashes (Plates I and XII) that open channels along which the milk can flow until it is all brought to one side of the tree, whence it is led down to a cavity hollowed in the ground and lined with the tough leaves of Calathæa. These are dexterously lifted up, and the milk is poured out into a calabash or other vessel and carried away to be coagulated. The diagonal channels are from 2 to 3 feet apart, and those of each successive tapping are inserted between the older scars. The diagonal lines are carried well around the tree; to tap it on the other side requires much deeper cuts in order to pass the milk across the older grooves, down which it would otherwise run and be lost. That the trees at La Zacualpa had been able to survive so much of this barbarous treatment and were still vigorous and heavily laden with fruit seems to indicate great tenacity of life. And yet even this rough handling represents an improvement upon the former custom of cutting the trees down entirely or hewing steps in them for the ulero to climb up. Instead of the forked stick used as a ladder at La Zacualpa the large forest trees were ascended for 30 feet or more by means of ropes, vines, climbing irons, and steps cut in the trunk. The following is a description of a method of tapping the trees in the forests of Nicaragua:

> When the collectors find an untapped tree in the forest they first make a ladder out of the lianas or "vejucos" that hang from every tree. This they do by tying short pieces of wood across them with small lianas, many of which are as tough as cord. They then proceed to score the bark with cuts which extend nearly around the

tree, like the letter V, the point being downward. A cut like this is made about every 3 feet all the way up the trunk. The milk will all run out of the tree in about an hour after it is cut, and it is collected into a large tin bottle made flat on one side and furnished with straps to fasten onto a man's back. A decoction is made from a liana (*Calonyction speciosum*), and this, on being added to the milk in the proportion of 1 pint to the gallon, coagulates it to rubber, which is made into round, flat cakes. A large tree, 5 feet in diameter, will yield, when first cut, about 20 gallons of milk, each gallon of which makes 2½ pounds of rubber. I was told that the tree recovers from the wounds and may be cut again after the lapse of a few months; but several I saw were killed through the large harlequin beetle (*Acrocinus longimanus*) laying its eggs in the cuts, and the grubs that are hatched boring great holes all through the trunk. When these grubs are at work you can hear their rasping by standing at the bottom of the tree, and the wood dust thrown out of their burrows accumulates in heaps on the ground below.[a]

AGE AT WHICH PLANTED TREES MAY BE TAPPED.

The earliest age at which Castilla trees may be tapped with safety and advantage has been stated all the way from four to twelve years, while from eight to ten years is the conservative estimate. At the same time it must be admitted that little in the way of positive knowledge exists on this point, and careful experiments may be necessary to determine whether, for example, the taking of half a pound of rubber from each tree in the sixth year will retard growth so as to diminish the yield of succeeding years. As the trees approach maturity and have occupied most of the available space, as much may be taken as will not weaken the tree and shorten its life.

The inferior quality of the rubber obtained from young trees also lessens the inducement for tapping them. It has been known for several years that the rubber and gutta-percha obtained from young plants or from the leaves and twigs of the trees is different from that yielded by a trunk of mature age, in that a smaller or larger percentage of rubber is replaced by nonelastic, brittle, or sticky substances commonly referred to as "resins." Dr. C. O. Weber has recently published the following results of analyses of samples of rubber from trees varying in age from two to eight years:[b]

Resins in rubber from trees—	Per cent.
2 years old	42.33
3 years old	35.02
4 years old	26.47
5 years old	18.18
7 years old	11.59
8 years old	7.21

The same writer also gives a table showing the varying amount of resin in samples from different parts of the same tree:

[a] The Naturalist in Nicaragua, Thomas Belt, F. G. S., pp. 33–34. The liana called by Belt *Calonyction speciosum* is generally called *Ipomoea bona-nox*.

[b] Tropical Agriculturist, 22:444, January, 1903.

Resin in rubber from—	Per cent.
Trunk	2.61
Largest branches	3.77
Medium branches	4.88
Young branches	5.86
Leaves	7.50

If these figures represent facts at all general, they lessen very distinctly the prospects of any plans which contemplate the tapping of very young trees, and it will be necessary to agree with Dr. Weber that eight years is the minimum age at which a plantation can be expected to furnish rubber for the market.

But as this point is one which has been brought into considerable prominence in recent years, and is being relied upon by some as a means by which the profits of rubber culture can be increased and hastened, it may be well to state that the inferiority of the rubber of young trees and growing parts has been determined by other competent investigators and especially by Mr. Parkin, whose account of the matter furnishes several interesting details which supplement the figures furnished by Dr. Weber:

In the case of Hevea, the rubber collected from the young stems and leaves, as well as from the unripe capsules, is somewhat adhesive, and has less elasticity and strength than that from the trunk. In the Castilla introduced into Ceylon the latex from the stems bearing leaves, as well as from the leaves themselves, molds between the finger and thumb into a very sticky substance, wholly unlike the caoutchouc-containing latex of the trunk. It dries to a brittle material, which becomes viscous when warmed. The quality of the rubber from stems of this Castilla, 12.5 to 25 centimeters (5 to 10 inches) in circumference, was likewise tested. It seemed to have properties intermediate between that of the shoots and the trunk, being slightly sticky and somewhat deficient in elasticity.

The climbing rubber plants, *Landolphia kirkii* and *Urceola esculenta*, show a similar difference between the latex from the shoot and that from thick stems. *Ficus elastica* also exhibits this peculiarity.[a]

Attention was called to this in Ficus as far back as 1839 by Weinlung. He called the substance "viscin," and considered it intermediate between resin and caoutchouc.

Mr. Parkin further says:

In many plants this so-called viscin seems to occur throughout the laticiferous system, e. g., the common bread-fruit (*Artocarpus incisa*) and jak (*A. integrifolia*), trees of the Tropics.

Most likely there are bodies which do not come within the categories of caoutchoucs and guttas, and yet are hydrocarbons with the same percentage composition. Probably some of these viscous substances are such. Also it appears probable that all caoutchoucs are not identical, and that when prepared as pure as possible from the latex, as by the ingenious centrifugal method of Biffen, it may be found, for example, that the caoutchouc of Hevea has slightly different properties from that of Castilla.[b]

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[a] See Weiss, Trans. Linn. Soc., III, 1892, p. 243.

[b] Parkin, Annals of Botany, **14:** 203–204, 1900.

DIRECTION AND SHAPE OF INCISIONS.

The tubes which produce the milk of Castilla and other rubber trees are so slender and thread-like that the creamy liquid would not flow from their cut ends if it were not forced out by pressure. Some writers seem to have assumed that the liquid is actually compressed inside the tubes, or that the walls of the tubes are stretched by the liquid they take up. A more probable view is that recently advocated by M. Lecomte,[a] that the pressure is due to the tension of the bark, and that it is mostly exerted in a transverse direction. If we add to this the fact that nearly all the tubes extend lengthwise, a transverse cut would reach the maximum number of these and would thus for two important reasons secure more milk than one of the same length in any other direction. A cut along the trunk would be the worst, since it would reach the fewest tubes and relieve the tension of the bark most. Oblique cuts are intermediate, the more horizontal the better. M. Lecomte hesitates to recommend transverse cuts lest they may prove injurious to the tree; but if a short transverse cut will bring as much milk as a longer oblique gash there seems to be no real reason why it should be more harmful, providing, of course, the tree be not girdled, or too much bark be not cut away at one level. The practical difficulty with transverse cuts lies in the fact that it would be much more difficult to collect the milk, some of which will stay in the cuts, while the surplus will run down the trunk of the tree in many driblets instead of being brought together at the point of the V-shaped incisions generally used. The desirability of making the cuts as nearly transverse as possible should, however, be considered, and in districts where, as in eastern Guatemala, dependence is placed entirely on the "scrap" rubber, most of which coagulates in the cuts or on the surface of the trunk of the tree, it may be feasible to make the cuts nearly or quite transverse. Indeed, this is what Dr. Preuss describes as customary on the El Baul plantation in Guatemala:

For tapping they use an instrument made out of a bush knife (machete). The end of the blade is for this purpose bent back until a groove is formed about broad enough to lay a finger in. The cutting edge of this groove is well sharpened. With this instrument the workmen tear *horizontal* gashes in the bark of the trees, and indeed over a half or three-quarters of the circumference of the trunk. The grooves are cut at distances of 1½ feet, one above another, up to the principal branches. The milk at first flows out in drops, which fall to the ground. They let these go to waste because the quantity is only small and this milk is very watery. But in a minute or two the dropping ceases and the milk which then oozes out is pulpy and remains in the furrows, where it hardens into strips of rubber. In two days these strips are pulled out, washed, and dried in the shade, and are then ready for market. Drying in the sun causes the rubber to become sticky and should be strictly avoided. The trees are tapped four times a year; each time another side of the trunk is operated

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[a] Journ. d'Agri. Tropicale, **10:** 100. Translated in Agriculture Bul. Straits and Federated Malay States, **1:** 382.

on. The yield each time is half a pound of rubber, or one kilogram (2.2 pounds) in a year. I was informed that the horizontal grooves made with the instrument described require only a quarter as much time to fill up as the broad diagonal wounds made with the machete. The former are completely closed in three months' time, and the tree recovers very rapidly.

Parkin's experiments in tapping Hevea in Ceylon gave results much in favor of oblique incisions over either horizontal or vertical. He says:

In both cases the oblique incision yields about double that of the other. There seems little difference between the amount collectible from a vertical and a horizontal incision. Although there is a greater output of latex from the horizontal cut, yet much more dries on the wound than in the case of the vertical, consequently the amount which drops into the receiver comes to about the same in the two cases.[a]

With Hevea it was found that two oblique incisions joined below to make a letter V gave nearly twice as much latex as one alone. In case of Castilla, however, where the milk flows so much more freely, it was concluded that the most milk could be secured with the least injury to the tree by means of separate oblique incisions. Such cuts would certainly heal more readily than V-shaped wounds, since the bark frequently receives its worst injuries at the junction of the two incisions.

TAPPING INSTRUMENTS.

That improved methods and tools are to be used for cultivated trees is one of the points on which all the rubber planters agree, but as yet none of the many improvements suggested has attained any popularity, and it is at least doubtful whether any of the devices brought forward at this time is to be looked upon as a practical solution of the problem. Some inventors have worked on the erroneous idea that the rubber comes from the sap, like sugar from the maple, and have thus completely wasted their time.

An enumeration of some of the features essential for a good tapping instrument may save further labor on wrong lines.

The cutting edge must be keen, and must therefore be easy to sharpen. A thick or blunt edge bruises the wood and milk tubes, and this interferes with the flow of milk.

There should be a means by which the depth of the cut can be regulated, since it is important to cut deep enough to reach the milk and yet not so deep as to reach into the wood, but axes and chisels with shoulders to prevent too deep penetration are not promising because the thickness of the outer bark is variable. The shoulders also bruise the bark if the cutting is by blows. In British India it is thought that the best instrument for tapping the Para rubber trees is an ordinary carpenter's gouge.

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[a] Circular Royal Botanic Gardens, Ceylon, June, 1899, p. 121.

MULTIPLE TAPPING.

By far the most important recent discovery in connection with the culture of Para rubber in the East Indies is what may be called multiple tapping, or the repeated cutting of the edges of the wound to induce a renewed flow of milk. This is, it is true, by no means a new idea, since it seems to have been the regular practice of the rubber gatherers of Brazil; but their idea that the tree gave more milk after it had become accustomed to the operation seemed so childishly fanciful to Europeans that it has only recently been put to a practical test, and now there is much surprise to find that it is very decidedly correct. Perhaps the most striking instance is that described very recently from Selangor, where a single Para rubber tree 25 years old yielded 18 pounds of rubber in a period of two months.[a] A single ounce was obtained the first day, and 1½ pounds in the next five days. For 10 days the daily average was more than half a pound, and on the twelfth day a maximum of 12 ounces was obtained. A second tree yielded a total of 12 pounds 10 ounces of rubber. It was estimated that about seventy hours of labor was required to collect about 30 pounds of rubber from the two trees, or over two hours for each pound of rubber, which may be noted as an indication that the collection of rubber by this method will be expensive in proportion as it is carefully done, since it will require intelligent and somewhat skillful cutting to avoid too serious injury to the trees.

PROTECTION AGAINST THIEVES.

A serious obstacle to profitable rubber culture in some parts of Central America is the stealing of the milk by the natives, and especially by those who have been accustomed to make a living from the tapping of the wild trees. Trouble from this source is likely to be much worse in countries where rubber is a natural product than in regions where the natives have not been accustomed to gather and sell it, and where no recognized trade exists to make easy the marketing of the contraband product. According to Dr. Carl Sapper,[b] long a resident of Central America and widely acquainted with social and agricultural conditions, many landowners have given up rubber culture because they find themselves unable to guard their trees from thieves who do not even wait to rob them of their crop, but destroy the young trees as soon as they begin to produce. A similar report is current from the banana-growing districts of the eastern seaboard of Central America, where experiments in rubber culture are said to have been given up not because the trees failed to grow but because

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[a] Agricultural Bulletin of the Straits and Federated Malay States, **1**:556, November, 1902.

[b] Der Tropenpflanzer, **3**:585, 1899.

the planters found that they would be unable to harvest their crop. In the West Indies and in many other tropical countries it has been found difficult to grow fruits and other food crops in proximity to a lawless native population, but rubber is even more difficult to protect, because of its high value, its continued presence in the tree, the ease with which it can be taken, the long time it can be stored, its small bulk, and the facility with which it can be transported and marketed.

These facts will increase the hazard of many rubber investments and will render obvious the advantage of enterprises operated in settled communities and protected by stable and responsible governments, for in the waiting period of eight or ten years many vicissitudes may be encountered. The ease and profit with which a rubber plantation could be plundered would be equaled only by the havoc which would result from reckless depredation.

To meet ordinary needs of protection two expedients may be suggested. In countries which are anxious to encourage the preservation and planting of rubber others than landowners and planters could be prohibited from marketing crude rubber or from having it in their possession, merchants being compelled to account for their exports by purchase from such authorized persons. On the other hand, the use by planters of special tapping tools not obtainable by the natives would make it possible to detect the theft of rubber, which is now extremely difficult. Indeed, the estates are often robbed by their own employees, and the rubber sold from "our own trees" by some of the companies is said to be purchased from thieves who save the owners the trouble of gathering their rubber.

The problem of rubber gathering is thus a real one which should be attacked with vigor and persistence. Not only are the present Central American methods quite unsuitable for use with cultivated trees, but there is a scarcity, and in many districts a complete absence, of laborers capable of applying even the present barbarous treatment. If their cultural efforts should prove successful it will be but a few years when plantation managers who have set out trees by the hundreds of thousands may find themselves unable to extract the liquid wealth. The temptation will then be great to end the tedious waiting for results by turning the plantations over to the mercies of the "huleros," if, indeed, it be found practicable to prevent them from helping themselves.

METHODS OF COAGULATING THE LATEX OF CASTILLA.

COAGULATION BY CREAMING.

The separation of rubber from the latex, a process commonly called coagulation, is in a somewhat more advanced state of investigation than the subject of tapping, if, indeed, the recent experiments of

Dr. Weber do not mean that a final and satisfactory conclusion has been reached. Dr. Weber finds that by the simple expedient of diluting the fresh latex of Castilla with five times its volume of boiling water and adding 8 ounces of formaldehyde to each barrel of the resulting fluid, all the impurities to which the inferiority of Castilla rubber are due can be removed, since they will remain in solution, while after twenty-four hours the clean rubber will be found in a "snow-white cake" which can be lifted off the top. Dr. Weber contends that rubber prepared in this way is "absolutely free from solid impurities of any description, * * * either soluble or insoluble, organic or inorganic," and that it is equal or superior to the finest brands of Para rubber. The process is simple and inexpensive, and if the mechanical qualities of the rubber meet Dr. Weber's expectations when the practical tests of manufacturing have been applied, it would seem that the essential requirements of the problem have been met, and in any case valuable progress has been made. It seems, moreover, from the investigations made by Parkin in Ceylon that this method is capable of still further simplification.

When the latex of Castilla is mixed with water and allowed to stand, in the course of an hour or two the caoutchouc particles have all floated to the top in the form of a thick cream. The diluted latex of Hevea, on the contrary, shows no signs of creaming, even when submitted to a low temperature. The difference is most likely due to the larger size of the caoutchouc globule in the case of Castilla as compared with that of Hevea.[a]

Parkin found, however, an interesting difference between the latex of Castilla in Ceylon and that described from tropical America by Biffen, in whose results Weber may be said to acquiesce, since he holds that the albumens of Castilla latex are readily coagulated by alkaline solutions.

The proteid of the latex of *Castilla elastica* has also been investigated to some extent by Biffen. He found that the latex gives an acid reaction, and that on the addition of a little alkali it is coagulated. This he considered to be due to the nature of the proteid which exists as acid albumen in the latex; on neutralization it comes out of solution and gathers together the caoutchouc particles into clots.

Now, the latex of the Castilla introduced into Ceylon (*C. markhamiana*) does not behave like this. On the very gradual addition of alkali to the latex or to the filtrate (the liquid part of the latex without the globules of caoutchouc) no coagulation or precipitation occurs. Alcohol causes a coagulation of the latex and a copious precipitate in the filtrate, which is quite soluble again in water. Proteid is present in considerable quantity, about 4 per cent being indicated by analysis. Coagulation is brought about neither by acids nor by boiling. Thus it looks as if the proteid belongs to the class of albumoses. At any rate the type of Castilloa introduced into Ceylon differs in this respect strikingly from that of the true *Castilloa elastica* examined by Biffen.

These facts are of interest, not only from their bearing upon coagulation and function of latex, but because they indicate the extent to

[a] Parkin, Annals of Botany, 14:198, 1900.

which the latex and its constituents may vary under different conditions of growth. Parkin is probably in error in the idea that the latex with which he experimented belonged to *Castilla markhamiana*. The tree which was introduced by Cross from Panama to Ceylon is more likely to be the same as that with which Weber experimented in Colombia.

DISCOLORATION OF CASTILLA LATEX.

Incidental to his principal discovery Dr. Weber reports several observations of much interest, not alone in their practical significance, but also as illustrations of the mistakes which can be made in a subject so difficult of investigation as rubber. Thus it is found that the milk of Castilla contains not a trace of tannic acid, the presence of which has often been inferred, presumably because ferric chlorid produces the same color reaction with latex as with tannic acid, turning it dark green. This reaction Dr. Weber finds to be due to the presence of a glucoside, which also gives the latex its intensely bitter taste. The addition of tannic acid precipitates the albumens of the latex, so that the presence of albumens is itself deemed a sufficient evidence of the absence of tannic acid in latex of any kind.

The rapid color change of the milk of Castilla on exposure to the air is found to be due to an enzym or oxydizing ferment (oxydase), which is probably destroyed by the boiling water, as suggested by Parkin, to whose work Dr. Weber does not refer, although in this part of the subject it had covered the same ground.

Parkin reported as follows:

> Several latices, which are pure white when they first issue from a wound on the plant, rapidly darken on exposure to the air. This is due to the presence of an oxydizing ferment, or oxydase, which with the aid of the oxygen of the air acts on some constituent of the latex, changing it to a deep brown coloring matter.
>
> The latex of Castilloa is a good example. It rapidly darkens on exposure and dries to an almost black rubber. By creaming the caoutchouc particles can be separated from the dark beer-like liquid and made into a sheet of nearly colorless rubber. By quickly heating the collected latex the darkening is arrested, owing to the destruction of the enzyme.
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> The latex of Hevea collected from the tree trunk does not darken at all on exposure to the air, and, provided that molds and putrefactive organisms are kept away, rubber prepared from it remains indefinitely of a light color. On the other hand, the latex from the wall of the unripe capsule (fruit) changes on exposure from milk-white to black. The darkening is wholly prevented if the latex is quickly subjected to heat. No doubt there is an oxydase present in the latex of the capsule.[a]

The expression "coagulation of rubber" appears objectionable to Dr. Weber because he finds that it is the albuminous substances of the latex which coagulate and not the rubber itself, but this objection seems rather overtechnical, since, even in Dr. Weber's method, the rubber is collected and compacted, and for this process a name is still

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[a] Parkin, Annals of Botany, **14**: 199–200, 1900.

required. It is the albuminous substances incorporated in Castilla rubber which continue to ferment and putrefy, or otherwise contribute to the deterioration of the rubber, both crude and manufactured. In other words, it is the albumens rather than the resins which determine the inferiority of rubber, and the amount of resin contained in the latex of adult Castilla trees is held to be "entirely innocuous" and "absolutely unobjectionable." Dr. Weber continues:

I am quite aware that now and then all sorts of sinister actions are ascribed to the presence of resins in india rubber, but there is not the least particle of evidence to show that they are intrinsically detrimental. As a matter of fact, in the manufacture of quite a number of rubber goods, resins are deliberately added to the mixings.[a]

OTHER METHODS OF COAGULATION.

The traditional method of treating Para rubber in Brazil is to spread it in thin layers on wooden paddles, which are held over burning palm nuts. The highest grades of commercial rubber have been produced in this way, but the process is too slow, laborious, and disagreeable. There seems, however, to be ground for a suspicion that some constituent of the smoke, which is incorporated into the rubber, may have a beneficial effect upon its mechanical properties, and the previously cited adverse opinion upon the pure but unsmoked Hevea rubber from the East Indies seems to give further warrant for such a notion. The experiment of smoking Castilla rubber has been tried at La Zacualpa, but the result was a hopelessly sticky mass. The difference of behavior is, however, more likely to be due to differences in the latex rather than to differences in the rubber itself.

It is not to be overlooked that, while the high percentage of albuminous impurities in Castilla rubber has rendered the price lower and the removal of them should increase the price, yet it will reduce the quantity of the marketable product and will thus not be an unmixed advantage. All the methods of coagulation now in use bring about the incorporation with the rubber of a large amount of the albuminous substances of the latex. Dr. Weber claims that if none of the albumens are left out they will constitute over 25 per cent of the solid product and adds:

The native rubber collectors prepare the rubber from the latex in such a way that at least part of the aqueous vehicle of the latex is drained away before coagulation takes place, and consequently we never find a Central American rubber (crude) which contains as much as the above-stated quantity (25 per cent of albuminous matter), but lots containing from 9 to 13 per cent are quite common.[b]

The meaning of this sentence is not obvious, and it becomes still less so if we read it in connection with one which follows a little later.

Therefore, whenever we coagulate the rubber, we can only do so by coagulating it in conjunction with the albumen present, and we have at once a product possessing all the irremediable drawbacks which above we discussed at some length.

[a] Tropical Agriculturist, 22:444, January, 1903.

[b] Tropical Agriculturist, 22:442, January, 1903.

None of the native methods of coagulation enumerated by Dr. Weber shows any provision for eliminating any part of the albumen. There is certainly nothing of this kind in connection with scrap rubber, into which all the solid constituents of the milk are simply dried down and little escapes except by evaporation, and yet scrap rubber is commonly deemed of good quality. In coagulation by the acid or alkaline juices of plants or by soap, salt, or alum, or by the boiling of the juice, the only materials which escape are those which do not coagulate, so that it is difficult to avoid the inference that the percentage of albuminous matter is not constant or that it has been incorrectly determined.

At La Zacualpa was witnessed still another method of coagulation by which all the nonvolatile constituents of the latex are retained. The latex is spread in a thin coating upon the large banana-like leaves of a species of Calathæa, laid out on the hot bare ground in the open sun. This exposure to heat, light, and air turns the milk dark with great rapidity, and in a few minutes it has become firm enough to permit a second layer to be spread on. Subsequently two of the leaves have their rubber-covered faces pressed together by being trodden upon, and the rubber adheres to form a single leaf-like sheet from which the leaves themselves are easily stripped away. Three stages of the process and the finished product are illustrated in Plate XVII.

COAGULATION OF SCRAP RUBBER.

Whether due to a varietal difference in the trees or to climatic or other differences of the external conditions, it seems to be a general fact that on the more continuously humid eastern slope of Central America the milk of Castilla does not run from the trees in quantities which can be collected and treated by improved methods of coagulation, but hardens in the cuts made by the rubber gatherer, who does not carry home the milk but returns in a day or two to pull out the dried "scraps," as rubber obtained in this way is called in the trade. As both the quality and the price of scrap rubber are satisfactory, the chief objection to this method of harvesting is the greater number of cuts in the tree and the greater amount of labor necessary to collect it, though the latter objection is somewhat counterbalanced by avoiding the work of coagulation. The principal point is the amount obtainable, and this depends upon the question of climates and varieties rather than upon that of coagulation. According to Professor H. Pittier, 6 pounds of scrap rubber are sometimes taken from a single wild tree in Costa Rica; but while this amount is considerable it is much less than that claimed by Koschny for the same country.

PRODUCTIVENESS OF CASTILLA.

YIELD OF WILD TREES.

That the Central American rubber tree, or at least some of its species or varieties, may attain a very large size in nature and may yield a very large amount of rubber, there is abundant testimony. Such facts have, however, only secondary interest from the cultural standpoint, because there are no means of determining the age of such trees. It has been claimed that as much as a hundred pounds of rubber has been obtained from a single tree. Koschny relates that in Costa Rica in the earlier days giant rubber trees 10 to 13 and even 14 feet in circumference were commonly found. All such have been destroyed by the rubber gatherers. Nothing but second-growth and young trees are now to be found.

The early literature of rubber culture abounds in statements exceeding the fondest dreams which the modern stock company dares to put on paper. We may be certain, for example, that rubber culture would not be still a new industry in Central America if the planters of that region had found facts to warrant the statement published by Collins in 1872, which probably led to the introduction of Castilla into British India.

> A tree of about 18 inches in diameter bled by skillful hands in April would yield about 20 gallons of milk capable of giving 50 pounds of caoutchouc. This is, however, the maximum yield; the average is a little below this. A tree of from 20 to 30 feet to its first branches is expected to yield 20 gallons of milk, and each gallon of milk to give 2 pounds or 2 pounds 2 ounces of good dried rubber.[a]

This estimate was somewhat reduced by Mr. Cross who visited Panama in 1875 to procure Castilla for India. He says:

> A Castilla tree, with a diameter of $1\frac{1}{2}$ to 2 feet, if carefully and judiciously tapped, may be expected to yield about 12 pounds of rubber per annum. Of all the different species of rubber-producing trees, the *Castilla* should prove, under cultivation, the most remunerative.[b]

YIELD OF CULTIVATED TREES.

Two questions must be considered in attempting to judge of the value of reported yields of rubber from planted trees. One is the direct issue of veracity, the other the possibility of errors in some one or more of the many known and unknown ways in which these can come about. There can be no doubt that many direct and intentional misrepresentations have been published regarding rubber culture, and it would be quite gratuitous to suppose that those whose testimony on other points is obviously wrong have been more careful when discussing the subject of yield. Until it can be shown that somebody has had

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[a] Report on Caoutchouc of Commerce, p. 15.

[b] Report on the Progress and Condition of the Royal Gardens at Kew during the Year 1881, p. 13.

a motive for reporting yields as smaller than they actually were the average reliability of small yields must be taken to be greater than that of large ones, though not, of course, establishing the falsity of higher figures. To the writer, at least, it appears significant that not one of the reported large yields from planted trees of Castilla has been supported by the testimony of a disinterested witness of scientific standing or even of wide reputation in other lines. Moreover, it seems necessary to attach much importance to the fact that among many planters and other residents of Guatemala and southern Mexico, all more or less directly interested in the possibilities of rubber culture, none was found who had witnessed or who credited the higher figures, but many denounced them as misrepresentations injurious to the legitimate development of rubber culture.

An exceptional yield is still an exceptional yield, and not an average which can be used as the basis of general calculation of the profits of rubber culture. To be brief and explicit on this point it may be said that at the present stage of this inquiry 2 pounds per tree is looked upon as the reasonable maximum yield to be expected from adult trees of twelve years and upward, growing under favorable natural conditions. This is the highest estimate which is known to the writer as having been made by reliable planters of intelligence and experience; and some such hold that the probabilities lie nearer to half a pound than to 2 pounds. It is appreciated that this estimate is much smaller than many claims based on wild trees, and that it is much larger than the results reached on some of the earlier plantations would seem to promise. The estimate is not, however, made as an average of all published figures, but is reached rather by the elimination of unwarranted expectations from one end of the series, and from the other of disappointments due to adverse local conditions.

The writer's only opportunity of witnessing the extraction of rubber except by small knife cuts was at La Zacualpa, where two of the 14-year old planted trees were tapped for his benefit (Pls. XVI and XVII). This was about the first of May, at the end of the long dry season, an unfavorable time for such an experiment. The result was slightly over a pound of rubber, coagulated, and dried on Calathaea leaves as previously described; but no reasons were apparent for doubting the claim of the management that 2 pounds of rubber had been secured at one time from neighboring trees of similar size and equal age. The trees tapped were about a foot in diameter at 3 feet from the ground, and as shown by the plates, they had been tapped severely and repeatedly. On the same occasion an ulero brought in about 10 pounds of milk, from which 6 pounds of fresh rubber was obtained by coagulation with the juice of Ipomœa; the same pad of rubber weighs about half as much after a year's drying.

Koschny, whose paper on the culture of Castilla has been accepted in Europe as the most authoritative work on the subject, states that vigorous 8-year-old trees will yield without injury something over a pound of rubber from three tappings, but he gives no intimation that this represents an average of any considerable number of planted trees, and, while he claims that his rubber gatherers have secured as high as 3¾ pounds from wild trees eight or nine years old, the uncertainty in the age of wild trees prevents such figures being relied upon, as he himself admits in another place.

This uncertainty of the time factor greatly reduces the value of figures derived from wild trees, particularly if complicated with other variable elements. The quality of rubber is known to differ with the age of the tree, and the same may be true of the quantity. The size of a forest-grown tree is no indication of its age as compared with one grown in the open. Wild trees are subjected also to an amount of cutting which nobody would advocate for planted trees. If the trees at La Zacualpa had been ascended with ladders and the whole trunk tapped, twice as much rubber or more might perhaps have been secured, or say 4 or 5 pounds at a more favorable season, but such an extension of the wounds of the trunk might be too much for even the persistent vitality of Castilla in Soconusco.

The planted trees at La Zacualpa abundantly demonstrate the practicability of rubber culture, but they leave the question of yield quite in doubt, for during a period of several years the experiment was abandoned, or at least entirely neglected, by the former owners of the estate and the trees were left at the mercy of the local uleros, so that it is now as impossible to learn how much rubber has been taken from them as to know how large and how productive they would have been had they been protected while young and tapped only with care and moderation.

It will be several years before adequate information on the yield of planted Castilla trees can be had, because, even after the trees have reached a productive maturity of eight years, an equal or longer period may be needed for experiments with different methods and times of tapping, before it will be known how the most rubber can be taken out with the least injury to the trees.

PROFITS AND PROSPECTS OF CASTILLA CULTURE.

MANAGEMENT OF RUBBER PLANTATIONS.

The extent and character of the correspondence received by the Department of Agriculture during the last two years show that many readers will expect rubber culture to be discussed not alone from the standpoint of the planter, but from that of the investor as well. It does not follow that any agricultural industry which may be profitable for the individual planter will be equally advantageous for one who supplies only capital and has no personal oversight of his property. When business of any kind can be systematized and conducted on a large scale the duplication of many expenses can be avoided and the profits increased proportionally, but this is obviously not true to the same extent for all industries. A sugar plantation, for example, must have a factory with expensive machines, skilled workmen, and competent management. The output can be doubled or much further increased with relatively little additional expense; consequently the consolidation of sugar estates and the abandonment of small plantations has gone forward with great rapidity in the last decade. To open a modern sugar estate large enough to be economically conducted costs from $300,000 to $500,000 and many are still larger. The water supply, tanks, machinery, and buildings required on a properly conducted coffee plantation cost from $50,000 to $100,000 or more, or enough to give large estates a decided advantage in economy of production, though far less than in the case of sugar. Unless it be where irrigation works are also required, it is not claimed with sugar that, in the plantation proper, the very large estates are superior to those of small size; and where the small grower can sell his cane at fair prices at the factory he is not obliged to go out of business. Coffee, also, is still produced extensively on small estates, and, if cooperative "beneficios," or cleaning and curing establishments, existed, the berries could be produced as profitably in proportion on 100-acre farms as on estates of 5,000 acres.

This digression may, perhaps, be pardoned if it helps to make plain the fact that rubber companies owe their existence not to any obvious advantage which they will enjoy in competition with the individual planter, but to estimates of exceptional profits which have attracted the nonresident investor. The manufacturing side of rubber culture, the labor of preparing the product for market, is relatively smaller than with almost any other crop, and the need of centralization is correspondingly less. It is to be expected that processes and appliances for washing, separating, and coagulating the rubber will be introduced, but there is little indication that these will be very complicated or very expensive of installation. The profits of rubber culture will depend primarily on the selection of proper locations, economical methods of culture, effective management of field labor, careful tapping, and watchfulness against thieves. All of these things the individual planter can attend to as well or better than the large concern. To coagulate, cure, ship, and market the rubber will also be necessary, of course, but the outlay for these will be comparatively small. If rubber culture is to be highly profitable for stock companies it will not be less so for the small landowner. Indeed, it would be difficult to mention another crop which, from the cultural standpoint, appears so preeminently adapted for the individual planter and for remote localities where the carrying in of heavy machinery and the bringing out of bulky products would destroy the profits.

Unless combined with other crops, the long period of waiting tends to make rubber planting difficult and unpopular for individuals with small capital; but the same delay also increases the risk of larger enterprises because the productive resources of an estate remain longer in uncertainty, and the proof of the ability and efficiency of the field management must be deferred. In other industries, like coffee and sugar, such facts come much more quickly to the surface. This objection is somewhat counterbalanced by the fact that the capital required to plant, cultivate, and harvest a given area in rubber is less than with most other crops. Nevertheless, until rubber culture has emerged somewhat from the experimental stage its greatest expansion should be expected to take place not in new regions, but as an adjunct to industries already established. This is preeminently true of the recently developed rubber industry of the British East Indies, and it is in the same way that rubber culture is first to be encouraged in Porto Rico, Hawaii, and the Philippines. Experimental plantings by residents of all promising regions can be made with little expense to individuals, and with little danger of loss on large investments. Landowners will wish to know whether their estates will produce rubber, and will be repaid for their trouble by having seed available for further planting as soon as their trees reach maturity.

SECURITY OF INVESTMENTS IN RUBBER PLANTATIONS.

The possibility of large returns is a powerful attraction to investors, and often renders them blind to the equal or greater possibility of loss. The difficulties attendant upon the development of a new industry are seldom attacked until somebody has been persuaded that it will yield a fortune more easily than older lines of activity. The difficulties are, however, commonly much greater than at first anticipated, and, although persistence may finally justify the effort, the first estimates have to be revised in the light of practical experience. As already explained, not all rubber trees yield even 2 pounds of rubber; the trees will thrive where they will not produce rubber; climatic conditions are uncertain; labor is not always available; the cost of collecting cultivated rubber will probably be greater than for the wild rubber; quality and prices vary; managers may be incompetent or dishonest; and many other circumstances may conspire to prevent the realization of the investor's hopes. The large profits calculated from rubber culture on theoretical grounds have not prevented some estates from proving a total loss, and do not render rubber culture a more secure field of investment than other agricultural enterprises. A large margin of normal profits may lessen the danger of actual loss in an established industry, though it does not render the income permanent, but prosperity is very liable to invite competition. It is true that with rubber the decline of prices from this cause is likely to be a remote danger, but the more brilliant the success of the industry the greater would be the certainty of the extensive participation of all suitable regions.

To pick up from the surface of the ground large-sized nuggets of gold is very profitable, but to operate gold mines is often a losing venture. The ore may fall below the estimated richness, the mines may be difficult to drain, the machinery may be unexpectedly expensive, the wages may advance, or the management may prove dishonest. A rubber plantation yielding perpetually an abundance of high-grade rubber might be "as good as a gold mine," but investors must expect that the profits of plantations will be subject to vicissitudes. It may be legitimate to represent the profits of a certain rubber enterprise as more sure than its competitors in the same or other lines of investment, but those who claim that rubber enjoys any special or unique security either deceive themselves or wish to deceive others. The expenses for land, equipment, culture, and management will vary; likewise the yield, quality, and market price. If the margin of possible profit be larger than in older agricultural industries, the universal lack of experience makes it the more difficult and uncertain of realization. Moreever, the demonstration that rubber culture is really a highly profitable business would attract so many aspirants to fortune that the anticipated rise in the price of rubber might never be realized; and, although there is not likely to be danger of overproduction for many years to come, the "perpetual dividends" sometimes advertised can scarcely be insured. Finally, the artificial production of rubber is a distinct possibility, pursued by the chemists with eagerness and confidence, and the discovery of such a process might completely change the prospects of an investment in rubber culture.

The careless confusion of the milk or latex with the sap is responsible for many of the misleading representations that the profits of rubber culture are sure. Even the sending of stockholders or disinterested parties to count the thrifty young trees on the plantations does not insure the anticipated returns, since, as already explained, the growth of the tree either in nature or in cultivation does not certify the production of paying quantities of rubber. That rubber planting is as sure as raising wheat, apples, or strawberries, or keeping a dairy, are misleading statements, to say the least.

Even if rubber came, like sugar, from the sap of the tree, it would not follow that the yield would be uniform either in quantity or quality. Different varieties of canes and beets vary greatly in this respect, to say nothing of the influence of soils and climatic conditions. With older farming industries these elements of success or failure are known and reckoned with, but the rubber industry has only commenced the accumulation of experience.

Neither should it be deemed a sufficient guaranty of the success of a plantation, or even of the good faith of a company, that prominent names should be found among the shareholders or officers. Rubber planting is so far out of the range of ordinary business ventures that men who would be trustworthy guides on investments at home are by no means proof against the miscalculations which have disappointed experienced tropical agriculturists; and it is not to be expected that all rubber companies will be found exempt from the well-known plan of securing indorsement by presents of stock and other less direct considerations by which apparently responsible patronage is not infrequently secured for new enterprises which can be made to appear "perfectly safe." The history of some of the numerous companies which have been floated in England for operating rubber concessions and plantations would make very interesting reading for the American investor. American rubber-planting enterprises are now much more extensive and on a much more secure footing than the English, but that they will entirely escape similar difficulties is scarcely to be expected.

Knowledge is lacking by which it is possible to judge with confidence the prospects of all rubber plantations, but there is absolutely no reason why any particular failure of planted rubber should be taken to mean that no cultivated rubber will be productive or that all rubber culture must be a failure. All plant cultures, tropical and temperate, have had their beginnings, so that the fact that rubber is a new agricultural product affords not the slightest reason why it may not be successful. Yet it can not be maintained that rubber is "as safe as any other crop," for the reason that there has been no opportunity to accumulate the experimental knowledge which would prevent failures.

REQUIREMENTS FOR SUCCESSFUL RUBBER PLANTATIONS.

It is hardly possible to set forth the difficulties and uncertainties which beset rubber culture without appearing to discourage the planter and the investor, though in reality there is no such intention, but only the desire that unnecessary mistakes and losses be avoided. There is no wish to warn anybody against rubber culture, either in the tropical islands of the United States or in other countries. The warning is against the idea that success and large profits are or can be assured without the caution and discrimination required for other branches of agriculture and other lines of investment.

Many factors must contribute to the success of a rubber-planting enterprise, while the lack of any one of them may turn profit into loss. At the risk of repetition, it may be well to enumerate some of the more important elements:

1. *Natural conditions of climate and soil must be favorable.*—This can best be inferred from the careful study of the wild rubber trees and other native vegetation. It is not safe to proceed under general ideas that Castilla will be productive everywhere in the Tropics, or that there are large regions or belts uniformly suitable for rubber. It is not safe to rely upon even the fact that neighboring plantations are productive, unless similarity of soil and topography has been ascertained.

2. *The plantation should be reasonably accessible.*—Although the bringing out of the rubber may not be difficult, the transportation of more bulky products and of the building materials and supplies, as well as the traveling expenses of the managers and laborers, will mean continuous charges with large totals. Some of the rubber estates of Mexico have already encountered unexpected difficulties and expenses in opening roads and buying steamboats.

3. *There must be an adequate and regular supply of labor.*—The cost of labor is also obviously important. Labor conditions may be very different in regions not far apart. The prospect in Mexico and Central America is an increasing scarcity of labor, higher wages, and larger expenses for quarters, supplies, and oversight necessary to keep laborers on the plantation. The conditions are entirely different from those of the United States, where the employer's responsibility so commonly ends with working hours and pay day. The cost of labor in Porto Rico does not compare unfavorably with that of many tropical districts of the continent, and the remaining inequality is rapidly disappearing.

4. *Local government must be stable and efficient.*—Unless located in regions controlled by stable and efficient governments the protection of rubber plantations against thieves may become a very large expense, to say nothing of the misfortune of general insecurity of life and property.

5. *The climate must be reasonably salubrious;* otherwise the difficulty and expense of labor and management may be greatly increased. Recent discoveries in tropical medicine, particularly the fact that malaria and yellow fever are communicated by mosquitoes, make it easier than ever before to secure protection against these diseases. The fact that rubber does not require continuous humidity also permits the extension of rubber culture in more salubrious localities.

6. *Plantation managers must be capable, efficient, and honest.*—Investors in rubber culture and other tropical enterprises are far more dependent upon the managers of their plantations than they are likely to appreciate without practical experience. That there is a great scarcity of competent and reliable managers of tropical plantations is well shown by the princely salaries now being paid by several of the

German coffee-plantation syndicates of Guatemala. And yet it is no uncommon occurrence for managers to resign such positions and go to planting for themselves. Great physical endurance, unusual executive ability, inflexible integrity of character, and extensive practical and local knowledge must be combined in a man who is able to handle successfully and honestly the complicated affairs of a large tropical plantation. He must be expert, or at least efficient, in everything from ditch digging to diplomacy, and when he is once well established and well acquainted with the country and with native customs, languages, and laws he is, as it were, master of the situation, and can make money many times as fast as any "new comer," no matter how capable. Many of the estimates of the cost of opening rubber plantations overlook the cost of management entirely, while others place it at a ridiculously insufficient figure. Some rubber plantations are being opened by men who have other remunerative interests which have enabled them to accumulate tropical experience and local knowledge, and who can be replaced only with much difficulty and much additional expense.

Investors in rubber plantations can not, as a rule, give personal attention to the points detailed above, but they have at least the responsibility of deciding whether the home officers of their companies have considered these and other obvious requirements for success. Without entering further into details, it may be said that, if many of the companies conduct their plantations as recklessly as they make advertising promises, the plantations and the promises must alike fail, or succeed only by the merest chance. It is, perhaps, unfair to impugn the honesty and intelligence of the officers of such companies, but it is certain that their advertising matter is being prepared by persons who know little about tropical agriculture in general or rubber culture in particular, or by those who carelessly or intentionally misrepresent the facts. The appeal is to the cupidity rather than to the good sense of the investor, though it is probably superfluous to warn those who have not yet learned that safe investments, bringing annual dividends of from 20 to 200 per cent do not go begging in the newspapers and magazines, while millions are available for anything which can assure returns at 5 per cent. It is a fact full of significance that during two decades and upward, in which many experiments were made by individuals and small companies, no large and well-advised interests invested in rubber culture. The importers and manufacturers of rubber in particular constitute a very intelligentand well-endowed financial community, which has from the first been keenly alive to the future of rubber production, and yet it is only within comparatively recent years that capital from this quarter has gone into rubber plantations, and even this has been applied in experimental quantities rather than in amounts indicative of established confidence in the prospects of rubber culture.

OPINION OF THE UNITED STATES CONSUL-GENERAL IN MEXICO.

As an antidote to the advertising claims of the numerous rubber companies, investors would do well to consider the report of Consul-General Barlow on "United States Enterprises in Mexico," published recently by the Bureau of Foreign Commerce of the Department of State.[a] Mr. Barlow finds that about $500,000,000 of American capital is invested in Mexico, about $350,000,000 of this being in railroads, $80,000,000 in mines, $28,000,000 in agriculture, and the remainder in manufactures, banks, and miscellaneous enterprises. The tenor of the discussion of investments in tropical agriculture may be judged from the following extracts:

Many of them have given their authorized capitalization, running up into millions, as the amount of capital actually invested, when really the amount of capital paid in is a very small percentage of the authorized capitalization and the amount invested is still less, perhaps a few thousand dollars. The first cost of virgin land in the Tropics of Mexico is very small—say 50 cents to $1 per acre as a liberal average. Development work is expensive, and some of the older companies have no doubt spent considerable sums in improving their properties; but in a general way, the "monthly payment" companies have not invested much in Mexico, however much the small investors may have paid to the promoters for the privilege of holding stock in their companies.

It is pointed out that, while some of the agricultural companies are successful, "they are comparatively few." All persons are advised to visit Mexico before investing, and a definite warning is given that the promises of profits of 200 per cent and upward are fraudulent.

The whole Isthmus of Tehuantepec, and possibly the entire tropical section of Mexico, could be bought by capitalists residing in this city, and if there were any sure 200 per cent investments to be made in that region they would certainly be taken up by persons on the ground who are thoroughly familiar with the conditions there. The speculative bubble will be pricked one of these days, and the small investors in the United States will have a lot of prettily engraved shares of stock and some more or less valuable experience to show for the money they have invested. I am in receipt of an average of ten or more letters each week from persons of small means in the United States who desire to invest in tropical agricultural companies operating or claiming to operate in Mexico, asking for information and advice concerning such companies and investments. One reply covers the whole ground. That is, first, that rubber culture in Mexico is as yet purely in the experimental stage, and no reliable statistics or information could be given concerning its probability of success. Promises of dividends by companies who propose to engage in the rubber-growing business are purely speculative and theoretical. * * * A small investment made by a school-teacher or minister or laboring man in the United States in a foreign enterprise blindly, may be well made; but in nine cases out of ten, the money could be invested to better advantage in the United States.

It should in fairness be repeated that the above quotations are made as an antidote rather than as representing an entirely satisfactory statement of the rubber situation. It would have been very difficult if not impossible for such a discussion as that of the consul-general

[a] Advance Sheets of Consular Reports, December 22, 1902.

to have given a correct impression of the percentage of rubber planting enterprises which are not reliable, even if he had been able to give the matter detailed investigation. No general condemnation of rubber planting either by individuals or by "monthly payment" companies is justified, but the certainty of success is not such that the investor can afford to be careless regarding the intelligence and reliability of those in whose hands he places his financial fate; and the consul-general will have performed an important service to the public if his statements are heeded, not as a general discouragement of rubber culture, but as a counsel of caution in making tropical investments.

CONCLUDING SUMMARY.

The culture of the Central American rubber tree has passed the experimental stage in the sense that the practicability of the agricultural production of rubber has been demonstrated, but on the other hand it has been ascertained that the tree may thrive where it will yield little or no rubber. Under favorable natural conditions the culture of *Castilla elastica* bids fair to become very profitable, but the experimental determination of the factors which influence the production of rubber has scarcely begun.

In southern Mexico and Central America the regions well adapted to the culture of Castilla are much more limited than has been supposed. The presence of wild Castilla trees is not a sufficient evidence that a locality is suited to commercial rubber culture.

Differences in the yield of rubber are not due merely to the existence of different species and varieties of Castilla, but are also controlled by external conditions.

The functions of the rubber milk in the economy of the plant are not well understood or agreed upon by botanists, but there are numerous reasons for holding that in Castilla and many other plants it aids in resisting drought.

A continuously humid climate is not necessary to the growth and productiveness of Castilla; the indications are rather that the quantity of milk and the percentage of rubber are both increased by an alternation of wet and dry seasons.

In its wild state Castilla does not flourish in the denser forests, but requires more open situations. It is confined to forest regions only by the perishability of its seeds.

Castilla thrives better when planted in the open than in the dense forest; even young seedlings are not injured by full exposure to the sun, providing that the ground does not become too dry.

The planting of Castilla under shade or in partially cleared forests is to be advised only on account of special conditions or as a means of saving labor and expense.

The loss of the leaves in the dry season may be explained as a protection against drought, and does not indicate conditions unfavorable to the tree or to the production of rubber.

The falling of the leaves of *Castilla elastica* in the dry season renders it unsuitable as a shade tree for coffee or cacao. In continuously humid localities where the leaves are retained shade trees are superfluous and the yield of rubber declines.

The desirable features of shade culture, the shading of the soil, and the encouragement of tall upright trunks, are to be secured by planting the rubber trees closer together rather than by the use of special shade trees. Planting closer than 10 feet, however, is of very doubtful expediency.

The percentage of rubber increases during the dry season and diminishes during the wet. The flow of milk is lessened in dry situations by inadequate water supply, but at the beginning of the rains such trees yield milk much more freely than those of continuously humid localities. The claim that more rubber is produced in the forest or by shaded trees seems to rest on tapping experiments made in the dry season.

Continuous humidity being unnecessary, the culture of Castilla may be undertaken in more salubrious regions than those to which rubber production has been thought to be confined; the experimental planting of Castilla in Porto Rico and the Philippines becomes advisable, but extensive planting in untried conditions is hazardous.

No satisfactory implement for the tapping of Castilla trees has come into use. Boring and suction devices are excluded by the fact that the milk is contained in fine vertical tubes in the bark, which must be cut to permit the milk to escape.

In British India it has been ascertained that the Para rubber tree may be repeatedly tapped on several successive or alternate days by renewing the wounds at the edges. The yield of milk increases for several tappings and the total is unexpectedly large. It is not yet known whether multiple tapping is practicable with Castilla, or whether this new plan may not give the Para rubber tree a distinct cultural advantage over Castilla.

The gathering of rubber from trees less than eight years old is not likely to be advantageous; the expense of collecting will be relatively large, and the quality of such rubber is inferior, owing to the large percentage of resin.

The rubber of Castilla is scarcely inferior to that of Hevea. The supposed inferiority is due to substances which can be removed from the milk by heat and by dilution with water.

DESCRIPTION OF PLATES.

Plate I. Frontispiece. Planted Castilla trees about fourteen years old at La Zacualpa plantation, Soconusco, Chiapas, Mexico. The scarred trunks show that they have been tapped many times by the native method. The trees average about a foot in diameter and stand about twelve feet apart in the rows. They were planted in alternation with cacao, but this has mostly disappeared.

Plate II. The original engraving of *Castilla elastica*, somewhat reduced. The staminate flowers are much longer than those shown in Plates V and VI and the fruits are in much looser and more spherical clusters than those of Plate VII.

Plate III. Tip of branch of Castilla from Panzos, eastern Guatemala. Each leaf is covered when young by a large ribbed hairy scale. The young leaves appear much more hairy before they expand. (Natural size.)

Plate IV. Staminate flowers and leaf base of Castilla from Panzos, eastern Guatemala. The scales are larger and less numerous than in Plate V, especially along the margins. The hairs of the branches are shorter and finer. (Natural size.)

Plate V. Staminate flowers and tip of leafy branch of Castilla from La Zacualpa plantation, Chiapas, Mexico. (Natural size.)

Plate VI. Pistillate and staminate flowers of Castilla from La Zacualpa, Chiapas, Mexico. Pistillate flowers at the left, the staminate at the right. The curved stigmas show in the middle of the pistillate clusters. At the side of each pistillate flower there may be one or two small staminate flowers quite different from those borne on branches which have staminate flowers only. (Natural size.)

Plate VII. Clusters of ripe fruit, La Zacualpa, Chiapas, Mexico. The fruits are fleshy and of a rather reddish-orange color. (Natural size.)

Plate VIII. Planted Castilla tree 18 months old at La Zacualpa, Chiapas, Mexico. Grown without shade.

Plate IX. Castilla tree about 25 meters high, planted as a fence stake, Tapachula, Mexico. Said to be capable of yielding 25 pounds of rubber.

Plate X. Young Castilla tree, showing self-pruned temporary branches, La Zacualpa, Chiapas, Mexico.

Plate XI. Bases of self-pruned temporary branches of Castilla, La Zacualpa, Chiapas, Mexico. The one on the left shows an unusual character in being branched near the base. (Natural size.)

Plate XII. Five large Castilla trees standing together, La Zacualpa, Chiapas, Mexico. These trees are a part of the plantation shown in the frontispiece, and are nearly as large as trees standing apart.

Plate XIII. Yearling Castilla tree planted six months in the open, Panzos, Guatemala.

Plate XIV. Yearling Castilla tree at Panzos, Guatemala, of the same age as that shown in Plate XIII, but standing in the shade and showing retarded growth.

Plate XV. Thinly shaded Castilla plantation, trees 18 months old, La Zacualpa, Chiapas, Mexico.

Plate XVI. Native method of tapping Castilla tree, La Zacualpa, Chiapas, Mexico.

Plate XVII. Native method of coagulating latex. Fig. 1.—Spreading latex on Calathæa leaf, a leaf already coated shown at the right, lying in the sun to coagulate the rubber. Fig. 2.—Pressing the two coated leaves together, to unite the two sheets of rubber. Fig. 3.—Pulling the leaf away from the rubber. Fig. 4.—The finished sample of rubber, marked by the veins of the leaf.

Plate XVIII. Fig. 1.—Sample of rubber coagulated in a bowl by juice of the moonvine. Fig. 2.—Branches bearing clusters of ripe fruit. Fig. 3.—Base of tree severely injured by careless tapping, but making new growth and showing the persistent vitality of the rubber trees of this region.

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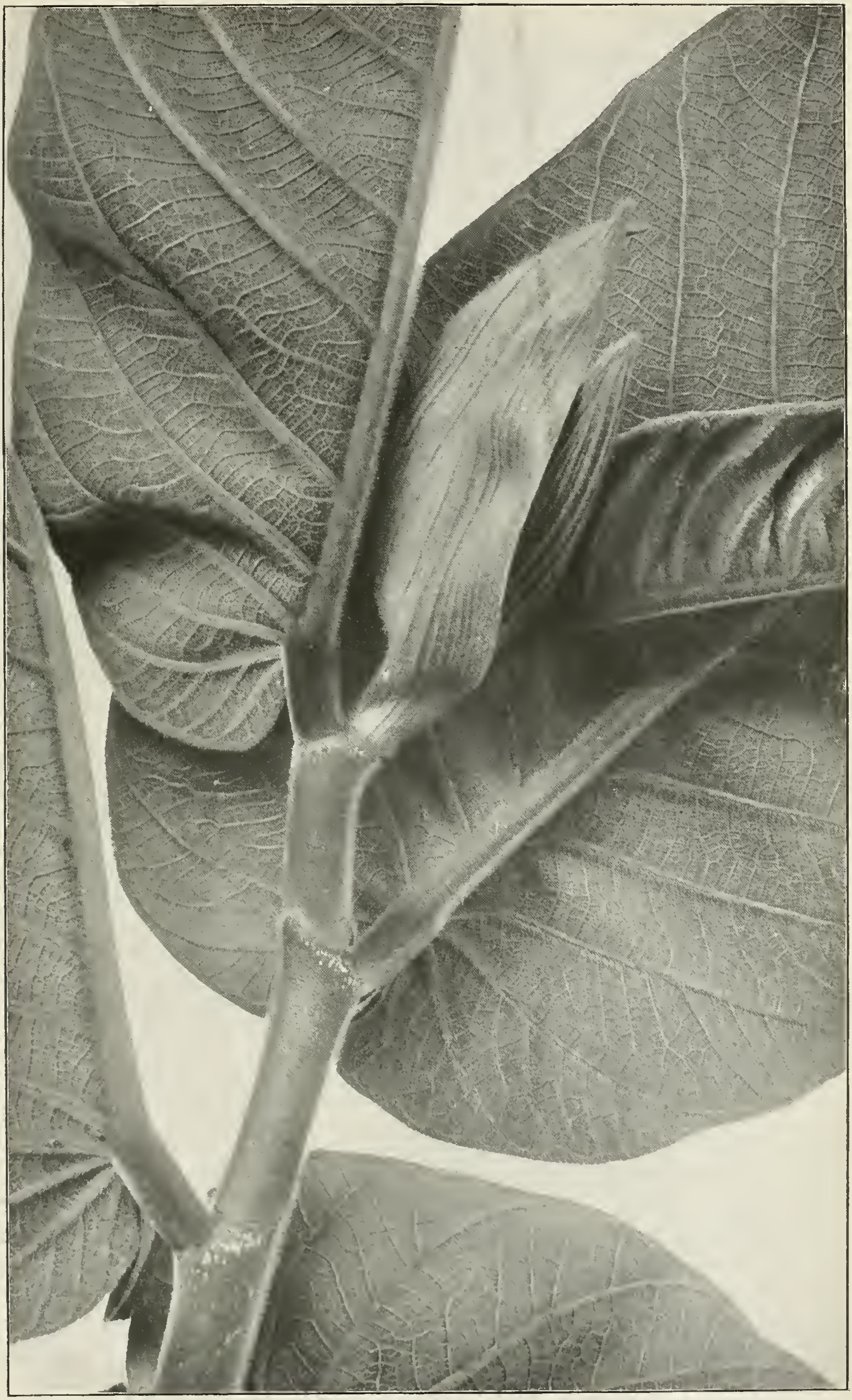
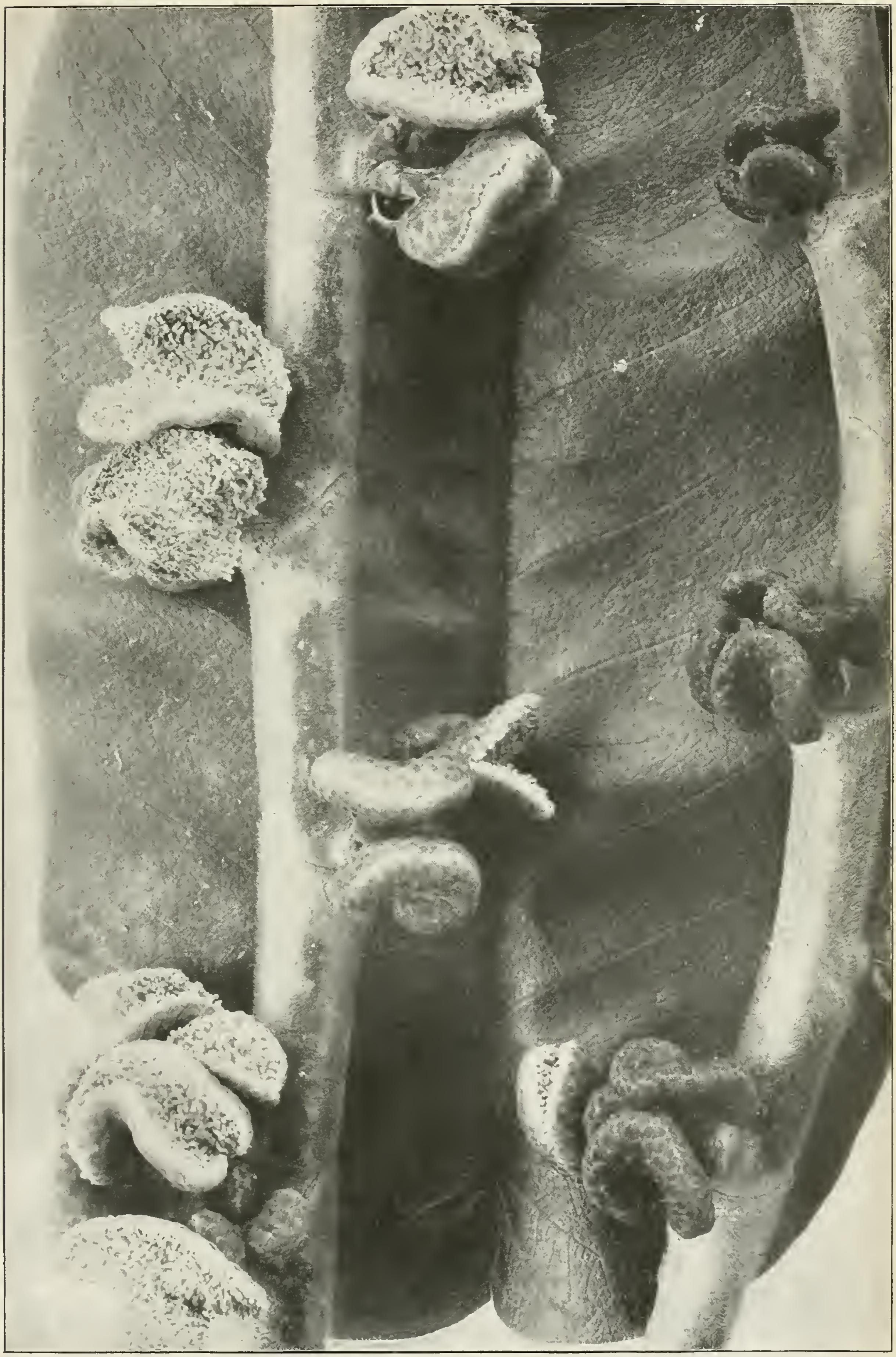
CERVANTES'S ORIGINAL ENGRAVING OF CASTILLA.

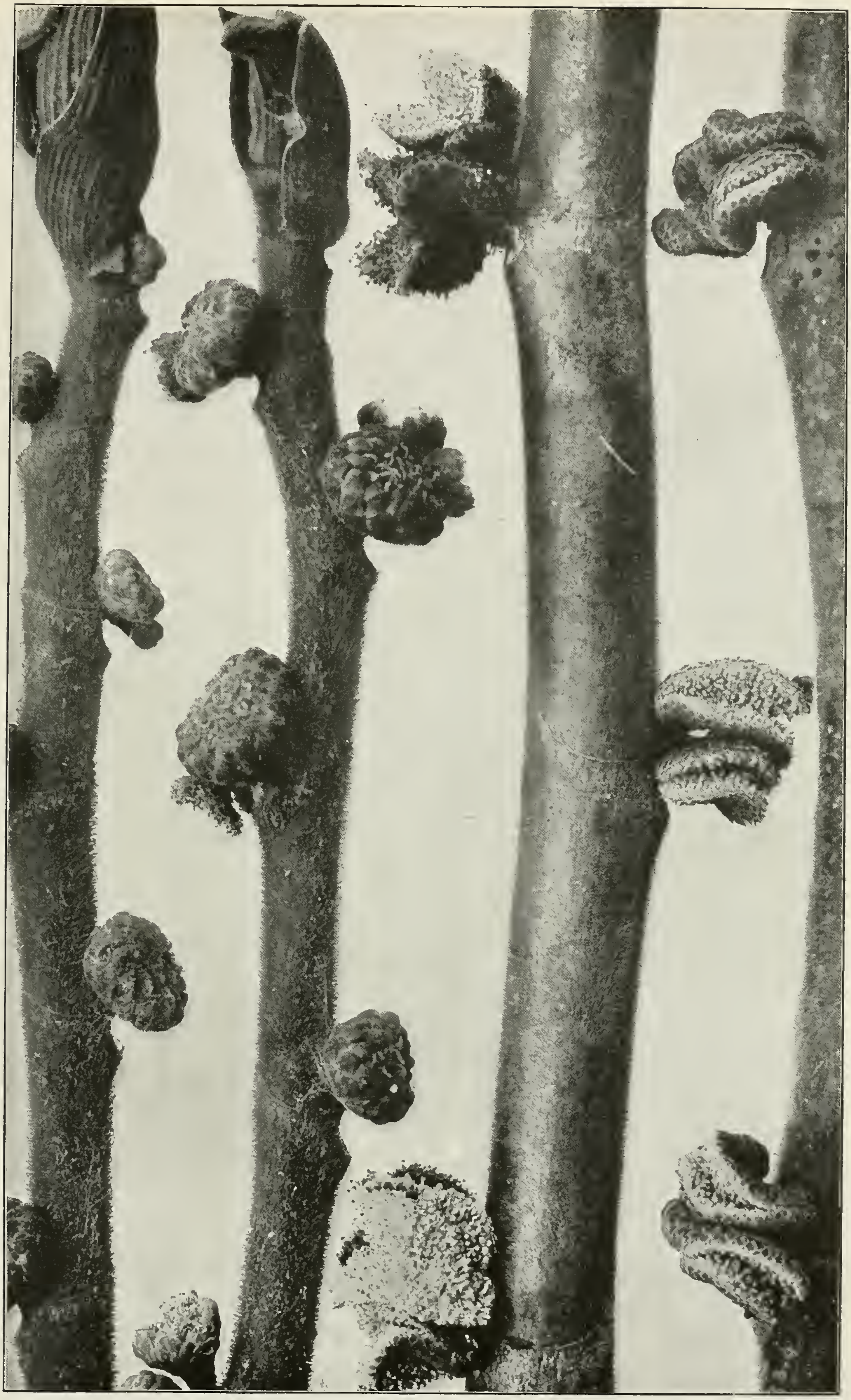


TIP OF BRANCH OF CASTILLA, EASTERN GUATEMALA (NATURAL SIZE).

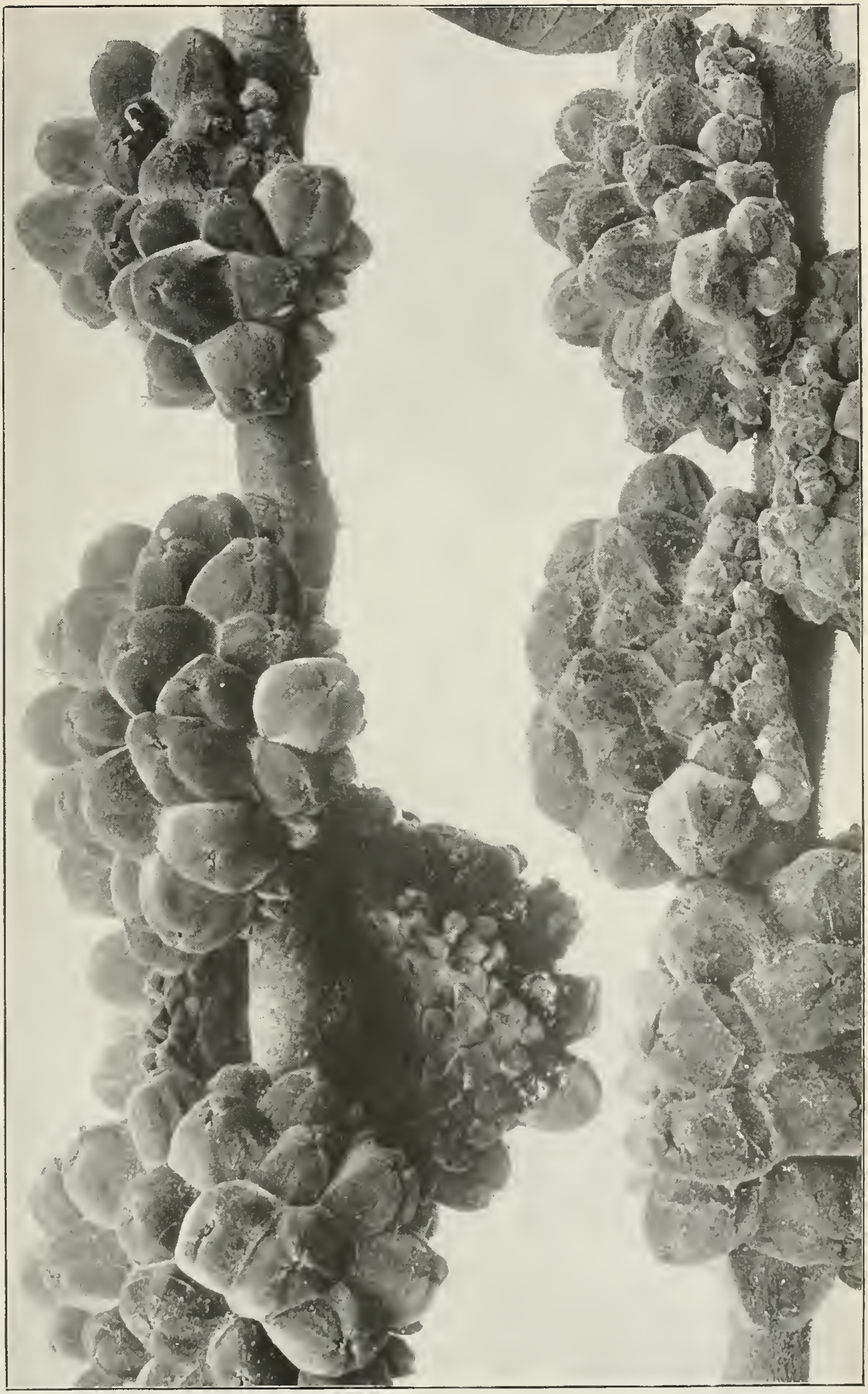


STAMINATE FLOWERS AND BASE OF LEAF OF CASTILLA, EASTERN GUATEMALA (NATURAL SIZE).

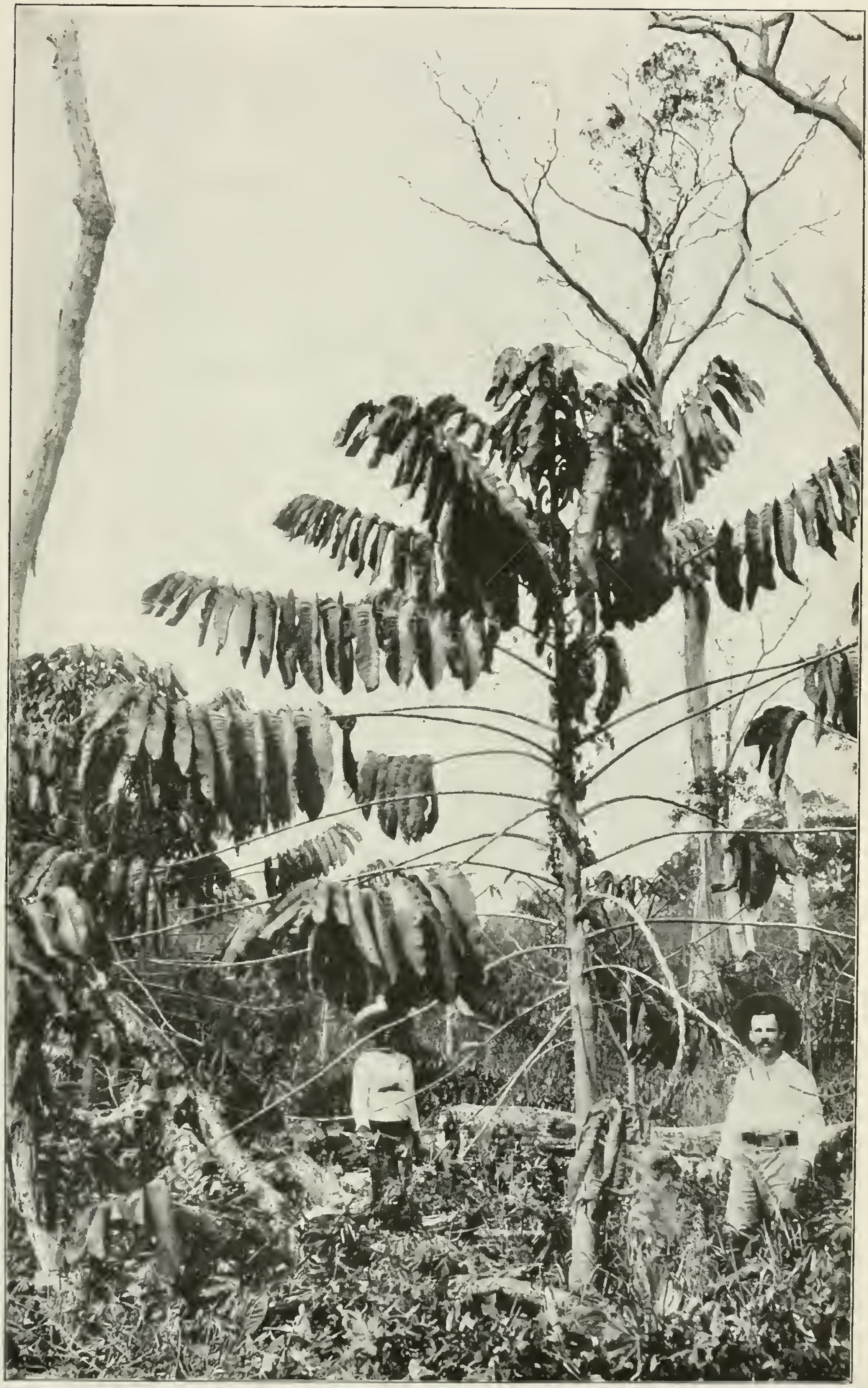
STAMINATE FLOWERS AND TIP OF LEAFY BRANCH OF CASTILLA, SOCONUSCO, MEXICO (NATURAL SIZE).



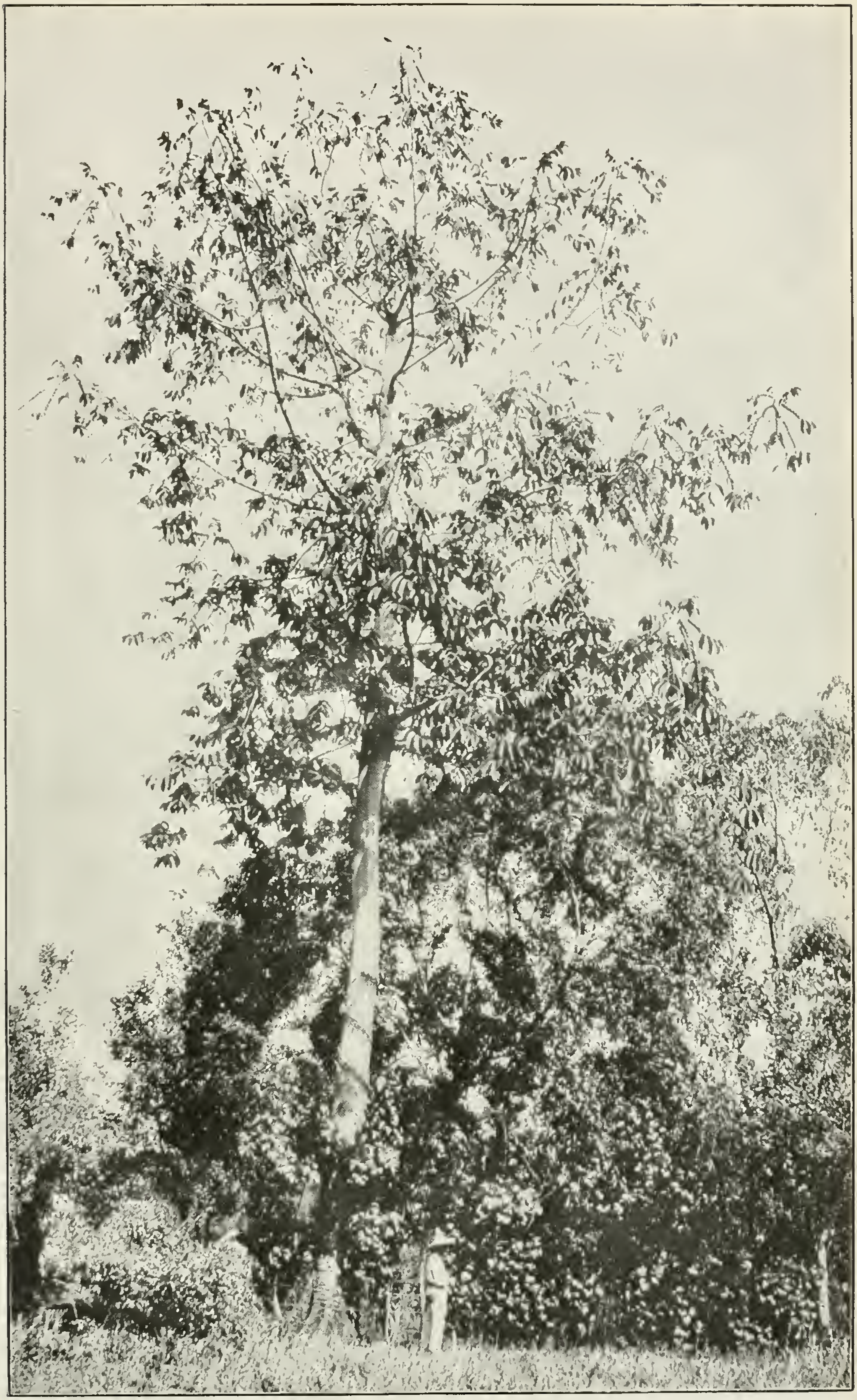
PISTILLATE AND STAMINATE FLOWERS OF CASTILLA, SOCONUSCO, MEXICO (NATURAL SIZE).



RIPE FRUIT OF CASTILLA, SOCONUSCO, MEXICO (NATURAL SIZE).

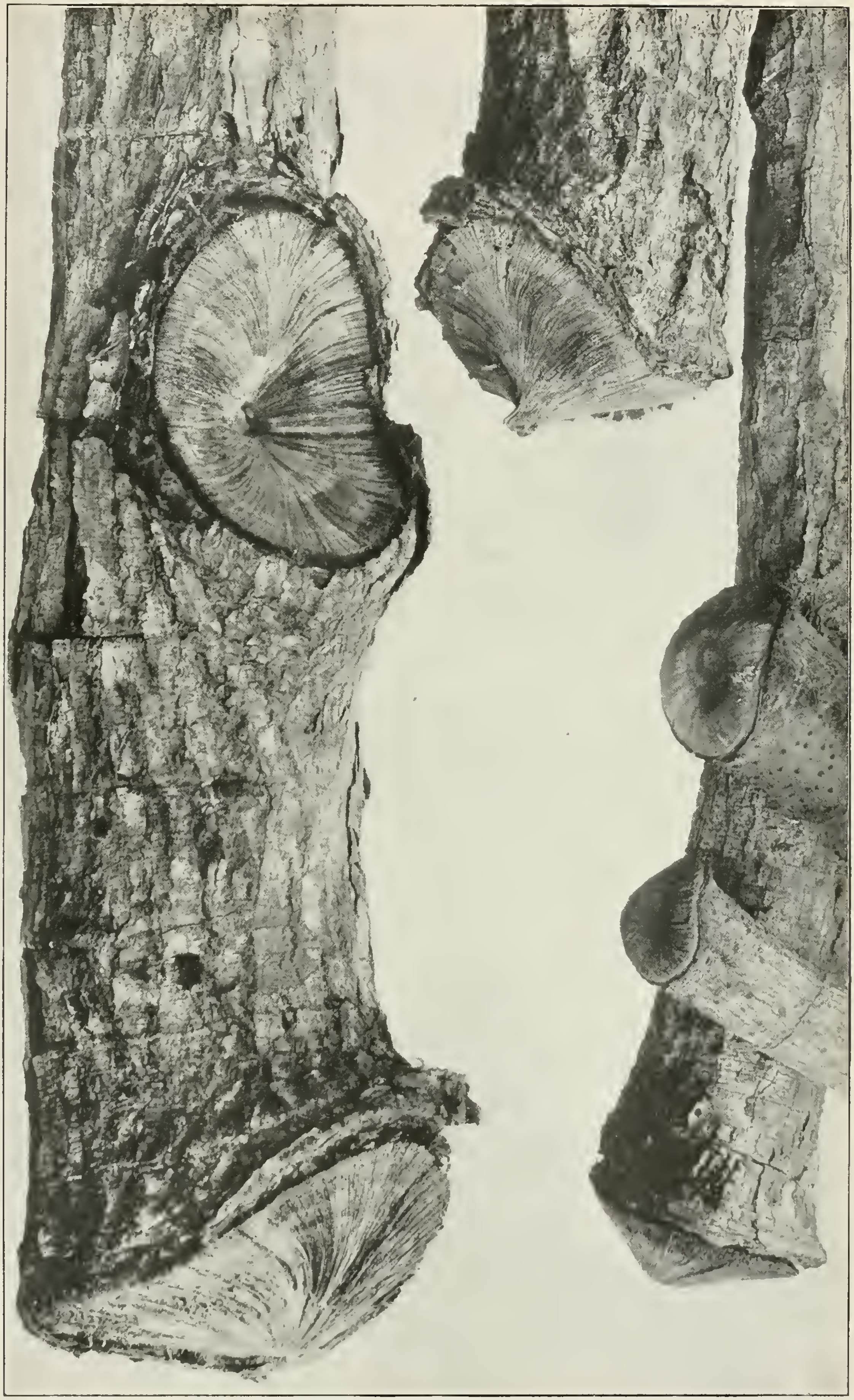


PLANTED CASTILLA TREE, 18 MONTHS OLD.



LARGE CASTILLA TREE GROWN FROM FENCE STAKE.

SELF-PRUNED BRANCHES OF CASTILLA.



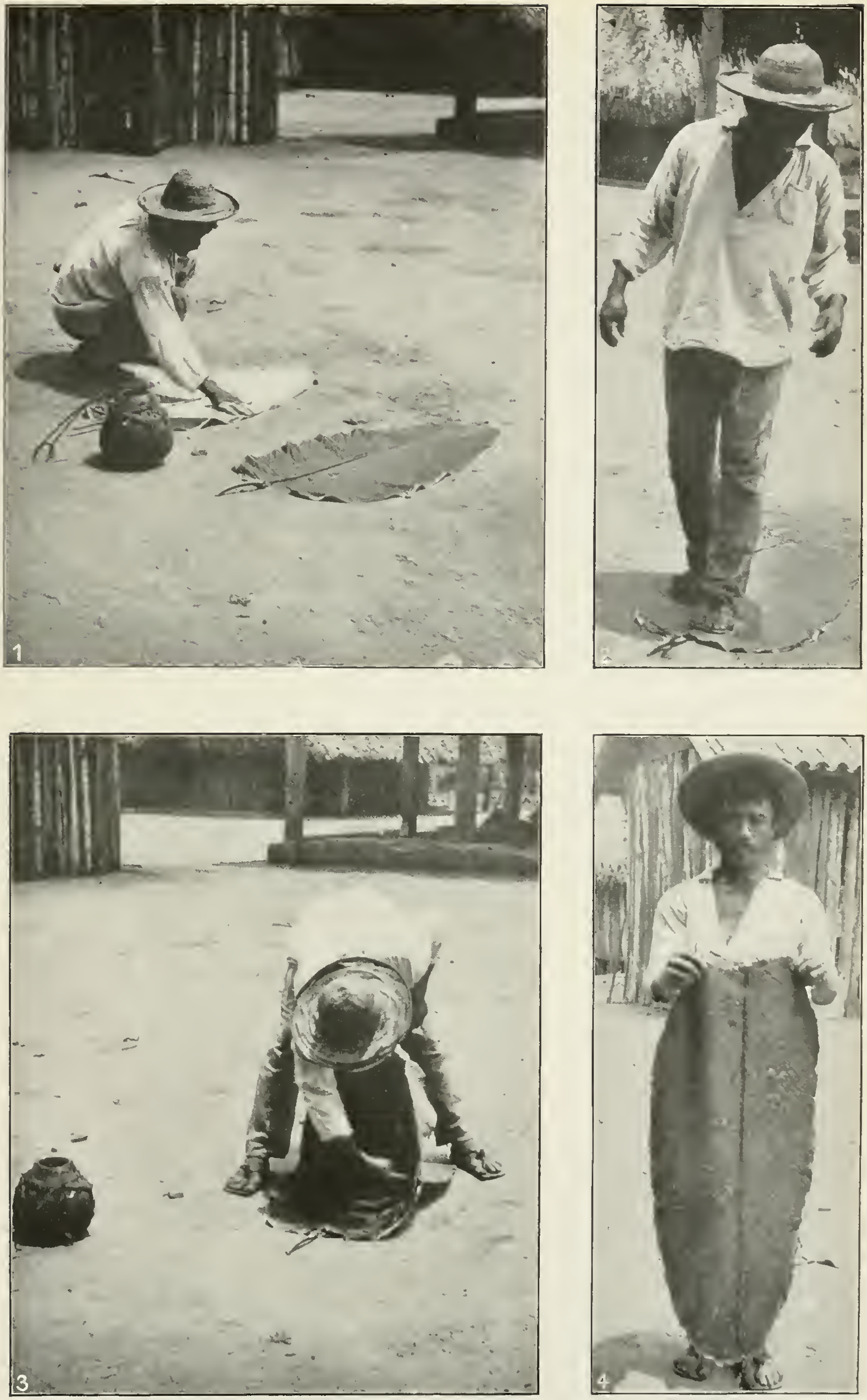
BASES OF SELF-PRUNED TEMPORARY BRANCHES OF CASTILLA (NATURAL SIZE).

YEARLING CASTILLA TREE PLANTED IN THE OPEN, EASTERN GUATEMALA.

YEARLING CASTILLA TREE PLANTED IN SHADE, EASTERN GUATEMALA.

THINLY SHADED CASTILLA PLANTATION, 18 MONTHS OLD.

NATIVE METHOD OF TAPPING CASTILLA.



NATIVE METHOD OF COAGULATING LATEX.

1, Spreading latex on Calathea leaf; 2, pressing two coated leaves together; 3, pulling the leaf from the rubber; 4, finished sample of rubber.

Fig. 1.—Rubber Coagulated by Juice of Moon-vine.

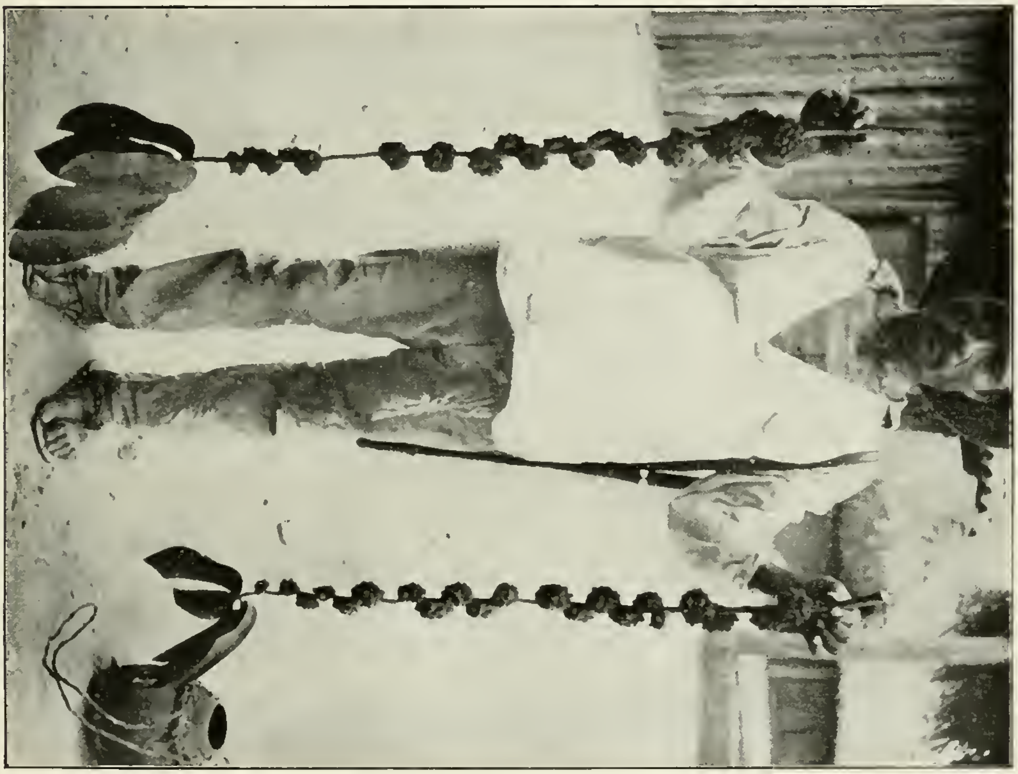


Fig. 2.—Branches of Castilla with Ripe Fruit.

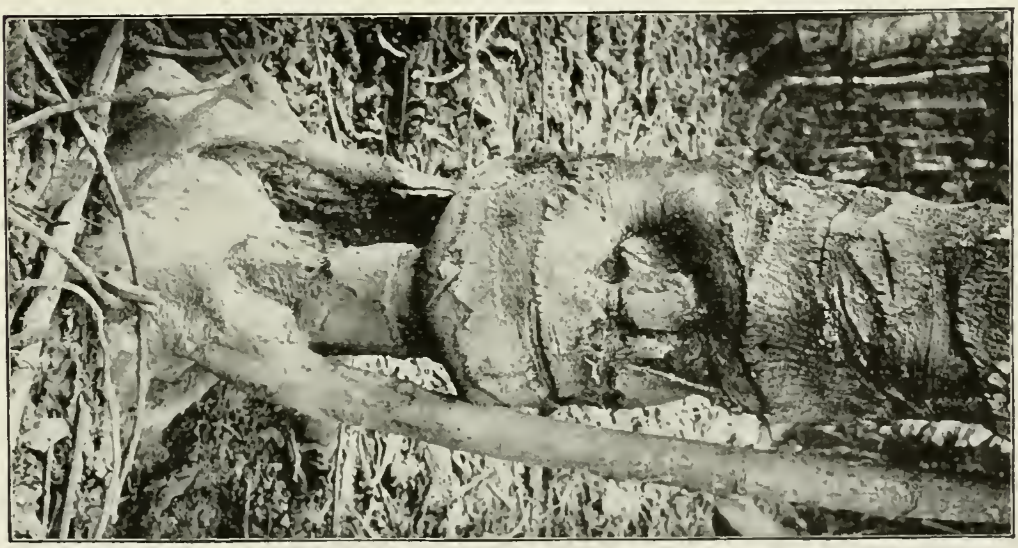


Fig. 3.—Base of Tree Injured by Tapping.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 50.

B. T. GALLOWAY, *Chief of Bureau.*

WILD RICE:

ITS USES AND PROPAGATION.

BY

EDGAR BROWN,
Botanist in Charge of Seed Laboratory,

AND

CARL S. SCOFIELD,
Botanist in Charge of Grain Grade Investigations.

BOTANICAL INVESTIGATIONS AND EXPERIMENTS.

Issued August 28, 1903.

WASHINGTON:
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1903.

BULLETINS OF THE BUREAU OF PLANT INDUSTRY.

The Bureau of Plant Industry, which was organized July 1, 1901, includes Vegetable Pathological and Physiological Investigations, Botanical Investigations and Experiments, Grass and Forage Plant Investigations, Pomological Investigations, and Experimental Gardens and Grounds, all of which were formerly separate Divisions, and also Seed and Plant Introduction and Distribution, the Arlington Experimental Farm, Tea Culture Investigations, and Domestic Sugar Investigations.

Beginning with the date of organization of the Bureau, the several series of Bulletins of the various Divisions were discontinued, and all are now published as one series of the Bureau. A list of the Bulletins issued in the present series follows.

Attention is directed to the fact that "the serial, scientific, and technical publications of the United States Department of Agriculture are not for general distribution. All copies not required for official use are by law turned over to the Superintendent of Documents, who is empowered to sell them at cost." All applications for such publications should, therefore, be made to the Superintendent of Documents, Union Building, Washington, D. C.

No. 1. The Relation of Lime and Magnesia to Plant Growth. I. Liming of Soils from a Physiological Standpoint. II. Experimental Study of the Relation of Lime and Magnesia to Plant Growth. 1901. Price, 10 cents.
2. Spermatogenesis and Fecundation of Zamia. 1901. Price, 20 cents.
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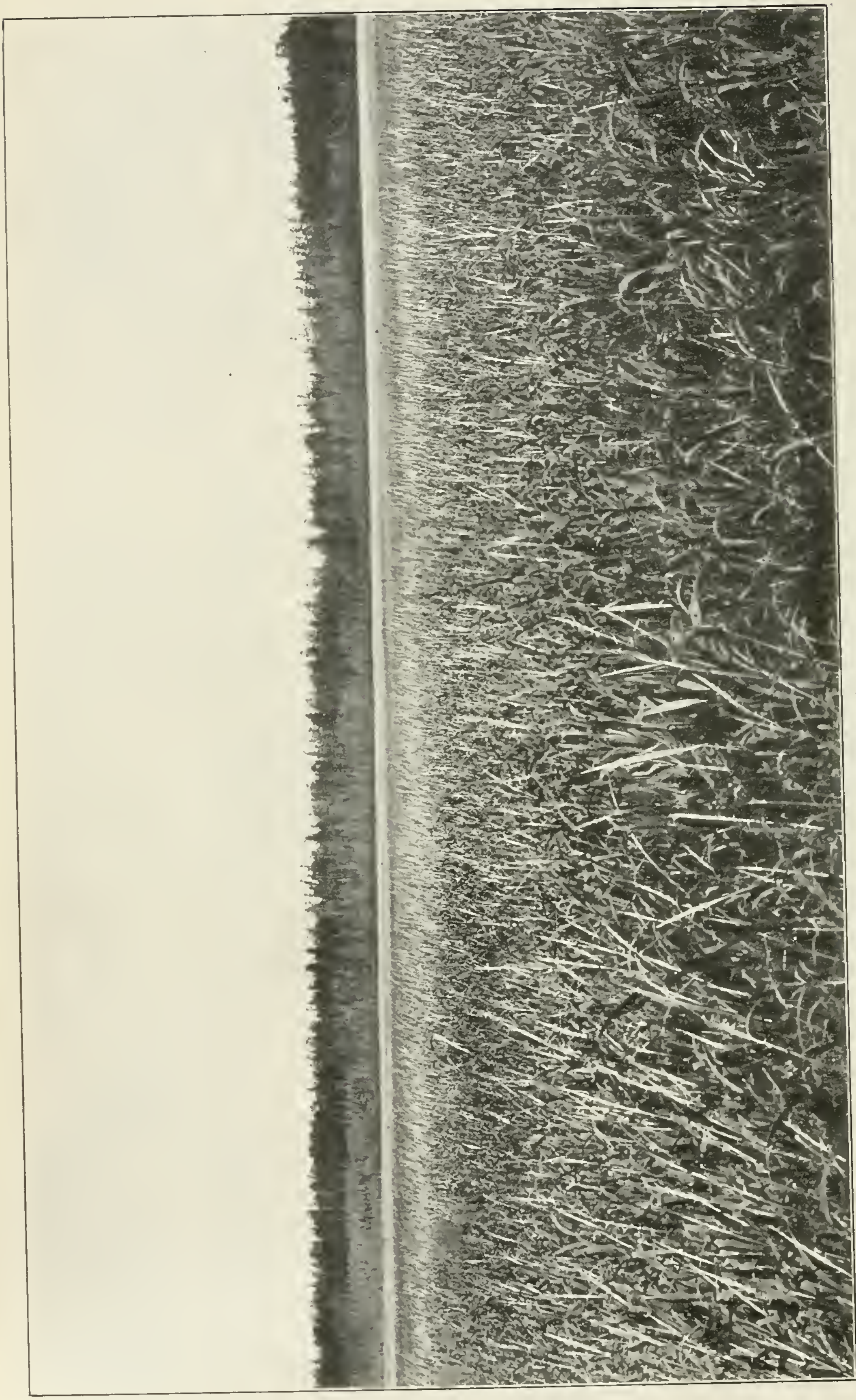
[Continued on p. 3 of cover.]



FIELD OF WILD RICE JUST HEADING OUT, NEAR BEMIDJI, MINN.

U. S. DEPARTMENT OF AGRICULTURE.

BUREAU OF PLANT INDUSTRY—BULLETIN NO. 50.

B. T. GALLOWAY, *Chief of Bureau.*

WILD RICE:

ITS USES AND PROPAGATION.

BY

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AND

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BOTANICAL INVESTIGATIONS AND EXPERIMENTS.

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PREFACE.

Wild rice (*Zizania aquatica*) is still an important, if not the chief, farinaceous food for probably 30,000 of the American aborigines, notably the Ojibwas. It is the principal fattening agent too for myriads of wild fowl in the eastern half of the United States. It is now being placed on the market in a small way as a breakfast food. On account of its great value as a food for game birds it has been widely and justly recommended as a suitable plant for shallow lakes and sluggish streams which are maintained as shooting preserves. The seed has been extensively marketed, but in most cases with results unsatisfactory to the buyer, for usually it fails to germinate. So nearly universal was the difficulty that some seedsmen who did not wish to disappoint their customers refused to handle the seed, or sold it only in small quantities. For a time it was supposed that the loss of vitality was due to the scorching to which the seed was subjected when gathered for food by the Indians, but it was found that seeds which had never been scorched failed also to germinate. It was then determined to try a series of experiments based on the observation that the grain of wild rice is still somewhat soft and moist at maturity and falls into the water immediately without hardening. These experiments, which are recorded in this report, show that the way to preserve the vitality of the seed is to keep it from becoming thoroughly dry, at the same time aerating it sufficiently to prevent molding. The practical course suggested to buyers is to place their orders before the time of the wild rice harvest, have the seed shipped immediately on maturity, and sow it at once.

The observations and experiments were delegated to two investigators, Mr. Carl S. Scofield, who made an examination of the plant in its natural situation in Minnesota, and Mr. Edgar Brown, who conducted the storage and germination tests.

FREDERICK V. COVILLE,
Botanist.

OFFICE OF THE BOTANIST,
Washington, D. C., July 3, 1903.

CONTENTS.

ILLUSTRATIONS.

B. P. I.—68. B. I. E.—54.

WILD RICE: ITS USES AND PROPAGATION.

INTRODUCTION.

The importance of wild rice as a food for wild fowl and the interest in its artificial propagation are indicated by the large number of inquiries regarding it that have come to the Department of Agriculture during recent years. These inquiries have emanated from many different localities widely separated, thus showing that the interest in this plant is not confined to any limited region. The general demand has been to know where viable seed of this plant could be obtained and how and where it should be sown to bring successful results. Some interest has also been manifested in the possibilities of preparing from this seed a commercial cereal food.

The seed of wild rice has been used for food by the Indians, particularly those of the middle Northwest, since as long ago, at least, as the first acquaintance of the white man with their customs. Notwithstanding the abundance of other forms of cereal food, such as flour and corn meal, since the advent of the white man, the Indian of the upper Mississippi Valley has continued to use large quantities of wild rice, and this too in spite of the fact that the harvesting and curing of the seed require considerable arduous labor. Wild rice, as prepared for food by the Indians, is highly esteemed by the white men who have had the opportunity of testing it and the entire available supply now sells at from two to three times the price of ordinary white rice.

While by far the largest demand for information regarding this plant has come from men or organizations wishing to secure viable seed for planting near shooting grounds to attract wild fowl, the possibility of preparing from the seed a large and regular supply of a nutritious and highly flavored cereal food has received some attention. The importance of maintaining good feeding grounds for wild fowl, of which the propagation of wild rice is a very important element, needs no discussion, and the desirability of propagating a plant which will make the otherwise waste-water areas of the upper Mississippi Valley yield a valuable and highly esteemed cereal is also evident.

DISTRIBUTION AND HABITAT OF THE PLANT.

The wild rice plant (*Zizania aquatica* L.) occurs naturally over a wide area in the United States and southern Canada. The same species is also reported from Japan, Formosa, and China. It finds its best environment in the United States in fresh-water lakes and river sloughs and along the seacoast where streams meet tidewater. It requires that the water in which it grows be fresh, that is, not brackish, and that it be neither quite stagnant nor too swiftly moving, and while it thrives on a wide variety of soils under these waters it does best where the bottoms are soft and muddy.

The change in water level where the plant grows is an important item. For instance, it will frequently fail to do well or to grow at all in some of the northern lakes through which the Mississippi flows, especially if the annual change in water level in these lakes is more than 2 or 3 feet. There is on this account in the minds of some observers an opinion that wild rice normally grows only alternate years, or at least that it does not grow every year in a given locality. This idea is without foundation and its existence is probably due to the fact that occasional years of high water prevent the development of wild rice for that year, while a normal level the following year permits the regular growth.

This calls attention to the peculiar vitality of the seed of this plant. It is evident that if the growth of wild rice in a given locality is wholly prevented for a year by high water and there is an abundant growth the next year when the water level is normal, there must be a large proportion of the seed which remains dormant and viable for at least eighteen months after it reaches maturity.

In streams affected by tidewater, however, where the daily change of water level sometimes amounts to 3 feet or more, wild rice may grow vigorously. It is abundant along the shores of the lower Potomac, where it grows on mud flats that are nearly or quite exposed at low tide and submerged by 2 to 3 feet of water at high tide. The plant has in this case become adapted to this frequent change of water level, but if for any reason high water were retained over these beds for any considerable length of time during the early spring the plants would hardly develop.

The following table shows the results of analyses of soils from various wild-rice fields. These results are given to show the general nature and physical condition of the soils of lake bottoms where wild rice ordinarily grows and to show the limits of the adaptation of the plant to the salty conditions found where fresh-water streams meet tidewater. These analyses were made by the Bureau of Soils of this Department.

Analyses of soil samples taken from the wild-rice beds near Bemidji, Minn.

Sample number.	Per cent passing 2-mm. sieve.	Per cent organic matter.	Per cent CO_2.	Per cent nitrogen.	Resistance of saturated soil.[a]
1	85.3	0.63	0.08	0.04	4,700
2	95.7	9.05	18.00	.20	1,208
3	98.9	10.89	26.17	.65	1,114

Analyses of soil samples from wild-rice beds on Potomac flats.

Sample number.	Per cent passing 2-mm. sieve.	Per cent organic matter.	Per cent CO_2.	Per cent nitrogen.	Resistance of saturated soil.[a]
4	87.7	6.00	0.20	0.14	805
5	98.3	3.61	.24	.18	1,141

Analyses of soil samples from wild-rice beds at Chesapeake Beach, Md.

Sample number.	Per cent passing 2-mm. sieve.	Per cent organic matter.	Per cent CO_2.	Per cent nitrogen.	Resistance of saturated soil.[a]
6	95.7	1.56	0.16	0.07	333
7	98.9	1.30	.23	.06	45
8	90.9	1.86	.66	.06	42

[a] This heading refers to the electrical resistance of the saturated soil. In a general way, the electrical resistance of a saturated soil varies inversely with the content of soluble salts. See Bulletin No. 8, Division of Soils, U. S. Department of Agriculture, "An Electric Method of Determining the Soluble Salt Content of Soils," by Milton Whitney and Thomas H. Means; also see "Chemical Examination of Alkali Soils," by Atherton Seidell, page 65 et seq., in Bulletin No. 18, Division of Soils, U. S. Department of Agriculture, "Solution Studies of Salts Occurring in Alkali Soils," by Frank K. Cameron, Lyman J. Briggs, and Atherton Seidell.

Water soluble constituents in soil samples from Chesapeake Beach, Md.

Sample number.	CO_3.	HCO_3.	Cl.	SO_4.	Ca.	Mg.	Na.	K.	Total.
	Per ct.	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
6	0.034	0.048	0.042	0.016	0.018	0.006	0.044	0.016	0.224
7	Trace.	.108	.380	.018	.084	.018	.174	.030	.812
8	Trace.	.120	.408	.062	.032	.022	.250	.032	.926

Sample No. 1 was taken from near Bemidji, Minn. The lake bottom at this point bore practically no vegetation except the wild rice plants. The soil was hard and sandy and covered with a thin layer of pine bark and débris. While the plants were not numerous, they were vigorous and apparently doing very well.

Sample No. 2 was also taken near Bemidji, Minn., from the midst of a wild rice field where the water was 21 inches deep and the soil was hard and sticky below a thin layer of soft mud. This layer of soft mud, which the sample represents, was about 4 inches thick at this point. Here the wild rice was not vigorous and the plants were branched very little, though they grew very thickly and stood 3½ to 4 feet above the water.

Sample No. 3 was also taken near Bemidji, Minn., from a locality where the wild rice was very thick and the plants were strong and vigorous and reached 6 feet out of water. The water was 21 inches deep and the bottom very soft for an additional 18 inches, and it was not firm for some distance farther down.

Sample No. 4 was taken from a wild-rice bed on the Potomac Flats, Washington, D. C. The water level here changes with the tide and varies from 6 inches below the level of the mud flat to 2½ feet above. The mud layer is 6 inches deep, underlaid with sand and gravel. The sample was taken from the 6-inch mud layer. The plants averaged about 7 feet in height and were vigorous and healthy.

Sample No. 5 was taken from another wild-rice bed on the Potomac Flats, Washington, D. C. The water level changes were as in No. 4, but the mud bank was higher, so that the water was only 14 inches deep at high tide. The mud layer had been made from dredging deposits and was 2 feet or more in depth. The plants were about 7 feet high, but somewhat less vigorous than those from the locality where sample No. 4 was obtained.

Samples Nos. 6, 7, and 8 were obtained from a wild-rice bed near Chesapeake Beach, on Chesapeake Bay. These samples were taken to determine the tidewater limits of wild rice or the amount of sea salt the plant can endure.

Sample No. 6 was taken where wild rice was growing thickly. The plants were vigorous, though rather small, not over 6 feet high and entirely out of water, but the soil was very wet and kept so by fresh-water seepage from a stream above.

Sample No. 7 was taken from near the same place as No. 6, but just outside the limits of the thick growth of wild rice, at a point where a single plant was growing feebly. This probably marks the extreme limit of adaptation of the plant to salty soils.

Sample No. 8 was obtained a few feet nearer the bay than Nos. 6 and 7 and where no wild rice was growing, but where the soil was supporting other vegetation.

Thus while it appears that wild rice will grow on a wide variety of soils, it needs for its best development approximately the following conditions:

Soft alluvial soil, covered with from 12 inches to 4 feet of water. The water level should not have an annual variation greater than 18 or 20 inches. The water should be constantly freshened by slight movement and consequent aeration.

LIFE HISTORY AND NATURAL PROPAGATION.

The wild-rice plant is an annual. It bears abundant crops of seeds which fall directly into the water as soon as ripe and lie buried in the mud below until the following spring when, if conditions are favorable, they germinate and produce new plants. In the northern lakes the long ribbon-like leaves appear floating upon the surface of the water late in May. By the latter part of June the stems have grown sufficiently to raise the leaves above the water. In the South the growth starts much earlier. On the mud flats of the lower Potomac the plants may be 6 inches high by the 1st of May. Strange as it may seem, the period of flowering and ripening of wild rice is almost the same in northern Minnesota and along the Potomac River near Washington, though on account of the earlier start in the southern region the period of growth is much longer.

The panicles appear during the latter part of July, and the flowers open immediately. The glumes of the pistillate flowers separate at the base to allow the stigmas to protrude and be pollinated and closing again soon after fertilization is accomplished leave the withered stigmas outside. Immediately after fertilization the young seed begins to elongate, and gradually fills the space within the floral envelope. This development requires about two or three weeks, and as soon as it is completed the connection with the stem is weakened and the seed falls off. The time of maturing of the different seeds in a single panicle extends over several days, the seeds on the tips of the branches ripening first.

The seeds on falling usually strike the water with the point of attachment below and sink immediately to the bottom. If by accident the distal end strikes first, enough small particles of air are caught by the barbs borne there to keep the seed on the surface of the water for a time, but as these air bubbles escape the seed sinks.

BOTANICAL DESCRIPTION.

Zizania aquatica L. is an aquatic, annual, monœcious grass. The stems are tall, erect, and hollow. The leaves are long and flat, with a heavy midrib, usually slightly nearer one margin of the blade than the other.

The flower cluster is a large panicle, bearing the staminate flowers on spreading branches below and the pistillate flowers on erect and more or less closely appressed branches above. The floral bracts are two in number, the outer five and the inner three nerved. The staminate flowers have six stamens. The pistillate flowers are borne with the larger glume toward the axis of the plant. The styles are nearly separate and stand at right angles to the floral axis, protruding on either side of the outer glume during and after fertilization.

The seed is nearly cylindrical in shape and long and slender, purplish black in color when mature, with a shallow crease along one side and a long, slender embryo.

GENERAL MORPHOLOGY.

For convenience in discussion we may consider the wild-rice plant as consisting of four principal areas: The Root, the Stem, the Leaf, and the Panicle.

The Root.—Unlike many grasses, wild rice produces upon germination but one root, arising from the embryo within the seed. The other two, which would make up the three commonly appearing from the seed of the grasses at germination, appear upon the first node of the shoot above the seed, which usually becomes the base of the stem, and from this and the nodes closely adjacent above arise the roots which maintain the life of the plant. In some cases large roots start from the first and even from the second node above the base of the stem in case a branch develops at either of these places and conditions are favorable, but for the most part the roots occur only at the base.

The base of the stem, shown in Plate II, fig. 2, is of peculiar curved shape. The roots arise in rows or whorls. The lower ones are slender and fibrous, while the upper ones, which are later and larger, function chiefly as a means of support or anchorage. The root system of the plant does not usually penetrate deep into the mud.

The Stem.—The stem of the wild-rice plant is essentially a hollow cone divided by four or five transverse walls at the principal nodes, which are the starting points of the leaves. Further divisions are made by transverse diaphragms which are called the pseudonodes. (Pl. II, fig. 1.) These pseudonodes occur at short intervals in each internode. It is probable that they function in making water-tight compartments to keep the plant afloat in case of injury to any portion of the stem, since the plant under normal conditions is held down by its roots rather than supported by them, and when released from its attachment to the soil readily floats to the surface of the water. These pseudonodes are probably the phylogenetic remnant of the pith of the stem, which has been preserved in this form as useful to the plant.

Branching of the stem is not uncommon, particularly when the plant is isolated or growing in shallow water. This branching usually occurs from the basal node or from the first node above, though rarely, if ever, does a branch which will mature arise from a node above the water. Vigorous branches arising from a basal node frequently throw out other branches, so that a cluster of several stems may arise from a single seed. In deep water, however, or where plants grow thickly there is little or no branching, even from the basal node.

The Leaves.—A leaf arises from each node of the stem and consists of the sheath, the ligule, and the blade.

The sheath clasps the stem closely and its edges overlap, completely covering the stem from the node from which it starts almost to the node above. The midrib is prominent in the sheath, as is shown in the sectional view in Plate II, fig. 1. The edges of the sheath are often streaked with purple, which color may also extend into the ligule or even into the blade of the leaf, being usually more pronounced near the margins of the part in which it occurs.

The ligule of the leaf is the thin, membranaceous extension of the sheath at the base of the blade, which clasps the stem above the sheath. (Pl. II, fig. 1.)

The blade of the leaf is peculiar chiefly in that its midrib is not in the center, being a little nearer one margin than the other. Those leaves which arise from the basal node or from the first node above the base are the ones which appear upon the surface of the water before the stem is developed. After the stem appears these floating leaves cease to function and wither away. The upper leaves, which are supported by the stem, do all the elaborating work after the stem appears and remain green and vigorous until after the seeds of the plant are mature.

The Panicle.—The panicle may be considered as having two areas—the staminate, which occurs below, and the pistillate, which occurs above. The staminate portion of the panicle consists of whorls of spreading branches arising from the joints of the axis. These primary branches bear numerous secondary branches, which in turn bear the flowers or spikelets.

The staminate spikelet consists of two unequal, soft, purple or pale green glumes inclosing six bright yellow stamens. The larger glume has five nerves and the other three. The larger glume bears a short, soft beak, and its edges overlap those of the smaller glume in the unopened spikelet. The stamens, after the spreading of the glumes, break open along their entire length and shed their bright yellow pollen out into the air, when it is carried by the wind to the stigmas of adjacent plants.

Cross fertilization of wild rice is insured because the pistillate portion of the panicle appears first from the leaf sheath and the stigmas have appeared and been pollinated by other plants before the staminate spikelets of the same plant have been released and opened.

The pistillate portion of the panicle is in the method of branching similar to the staminate portion, except that the branches are usually borne nearly or quite erect, in some cases being closely appressed to the main axis. The amount of spreading of the branches of the pistillate portion of the panicle is one of the important distinguishing marks between the varieties of wild rice. The spreading is due to the development of the prophyllum at the juncture of the branches with the main axis. When this prophyllum is well developed the branch is forced out and the panicle is spreading. When it is not developed the branch remains erect and closely appressed to the main axis. For the most part, the wild rice of the northern Minnesota lakes is of the type shown in Plate V, fig. 2, having the branches of the panicle closely appressed, though there are occasional panicles in which some of the branches spread. On the other hand, the wild rice growing in the vicinity of the District of Columbia has a very open or spreading panicle. (Pl. V, fig. 1.)

The pistillate flower has two glumes and a bifurcated, much-branched stigma, and two lodecules which surround and almost conceal the comparatively small ovary. (Pl. III, fig. 2.) The larger glume is five ribbed and bears at its summit a stiff, usually somewhat twisted awn of several times its own length, which bears numerous barbs or bristly hairs. There are also short bristles borne along the edge of the glume and a short distance down along each of its nerves. (Pl. IV, fig. 1.) All these barbs and bristles point toward the tip of the glume and are probably of assistance to the seed in burying itself in the mud. The smaller glume (Pl. III, fig. 2) is much more delicate than the larger one and is almost entirely inclosed by it. It has three delicate nerves and its tip is so surrounded by that of the larger glume that it is only with difficulty that they can be separated. When the seed reaches maturity and fills the glumes they are held so firmly together that they must be broken to be removed.

The bifurcated style and two lodecules are shown in Plate III, fig. 2. The styles are so bent as to stand at right angles to the axis of the ovary. The behavior of the lodecules at the time of fertilization is very interesting. By expanding, as the result of the absorption of moisture, they force the glumes apart at the base (Pl. IV, fig. 1), and at the same time the stigmas appear on either side of the smaller glume, where they are in position to catch any pollen that may be blown upon the plant. As soon as fertilization is accomplished the stigmas wither and the lodecules cease their pressure, the smaller glume again returns within the margins of the larger one, and the ovary begins to develop.

VARIETIES.

While distinct differences in size and form of panicle, the coloration of the plant, and the size of the seed have been noticed in wild rice from various regions, there is as yet insufficient evidence to justify making a new species. It is impossible to say at the present time to what extent these differences are due only to environment. The wild rice of northern Minnesota and that growing along the lower Potomac show the extreme variations in some respects. The Potomac plants grow 8 to 10 feet high and 6 to 7 feet above the water and have a very large panicle, often exceeding 2 feet from the lower joint to the tip of the pistillate end. The pistillate portion of the panicle in the Potomac plant is distinctly spreading and the branches often bear 17 to 27 seeds. The plant common to the northern Minnesota lakes is smaller than that of the Potomac, usually reaching only 3 or 4 feet above the water. The panicle is shorter, rarely if ever exceeding 20 inches in length, more often 16 inches or less. The pistillate portion rarely exceeds 10 inches in length and usually has its branches closely appressed. When spreading of the branches of the pistillate portion of the panicle does occur in the wild rice of the northern lakes it is seldom that all the branches of a panicle are spreading—frequently only 1 or 2 of them, rarely more than 4 or 5—and the branches of the panicle of the Minnesota plant rarely carry more than 9 seeds, usually from 3 to 7.

The following table of seed measurements is given to show the difference in size of wild rice seeds from different regions. These measurements were made on the seed after the hull was removed and are given in metric millimeters.

Wild rice seed from—	Number measured.	Length.			Diameter.		
		Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.
Potomac River	100	13.77	18.00	8.90	1.04	1.30	0.80
Port Hope, Ontario	50	19.29	23.30	14.20	1.67	2.00	1.40
Minnesota	50	12.00	15.10	9.00	1.65	2.28	1.30

It will be observed from this table that the seeds from northern varieties are larger, particularly much thicker, than those of the Potomac variety.

There is also in the northern-grown wild rice a marked distinction in coloration. Some of the plants are a rich purple color in the panicle and have a large amount of purple coloring in the leaf sheath and along the margin of the leaf blade, while others remain with almost no suggestion of any color but green, except perhaps a pinkish tinge in the glumes of the staminate flowers. The stamens in all cases are uniformly of a rich bright yellow, and the mature seeds are always black. Some seeds are green or greenish brown in color, but this is due to their immaturity. It is difficult to understand this difference in color in wild-rice plants. It has been shown that the plants are uniformly cross-pollinated, and plants of both colors grow side by side in the northern lakes, though in some localities plants of one color or the other predominate; and while one may find a few cases of colors intergrading between these two, the extremes of coloration are the rule, and, except in rare cases, marked coloration, when it occurs, extends throughout the plant. For instance, a dark purple pistillate panicle almost invariably accompanies dark purple staminate flowers and a large amount of that color in the leaf sheath and blade. Color variation is found in the Potomac wild rice, though to a much less degree.

DISEASES.

So far as has been observed, but one fungous disease seriously affects wild rice. This is a form of ergot (*Claviceps*, species undetermined, Pl. IV, fig. 2). This disease has been found widely distributed through the wild-rice fields of northern Minnesota, and though it is seldom abundant, no field was found in which close observation did not reveal its presence. If it occurs in large quantities in any place it is, of course, a decided disadvantage, as the seed is not usually so treated as to make the separation of the sclerotia at all easy, and serious damage might result from the use for food of badly infected seed on account of the poisonous properties of the fungus.

HARVESTING THE SEED.

Almost all the wild-rice seed now harvested is gathered by Indians into birch-bark canoes. This is done usually by two persons working together, one standing in the bow of the canoe and propelling it with a forked stick and the other seated in the stern with two short sticks, by means of which the plants on either side of the canoe are gently pulled over it and the ripe seed beaten off. No attempt is made to get all the seed off the plants at one time. It is customary rather to take only the seed which falls readily and to visit the same plants later as more seeds ripen. The period of ripening extends over nearly two weeks for any field and over several days for any single plant, so that were one to attempt to harvest all the rice on a given area it would be necessary to go over that area at least four or five times at intervals of from two to three days. Recently some attempts have been made to construct machinery for harvesting wild rice seed from boats driven by screw or drawn by cable. So far, however, such endeavors have not been entirely successful.

It is customary in some sections for the Indians to prepare wild rice for harvesting by going through the field before any of the seed is quite ripe to draw the heads of adjacent plants into bunches, which are firmly tied together, so that the seed, as it ripens, will not fall. This custom, however, is not universal, and is only resorted to when the supply of wild rice is not abundant and it is desirable to gather as much as possible from certain fields. When a portion of a field is so tied up it can be left until after all the untied seed has been harvested or has fallen, and in this way the harvesting period is extended. This preliminary tying is, of course, a tedious operation, and would be expensive were the time of the operator a salable quantity. The harvesting of wild rice is not regarded by the Indians as a particularly arduous task, though attempts by white men to do the same work have not proved very successful.

PREPARATION OF THE SEED FOR FOOD PURPOSES.

After the wild-rice seed is harvested into the canoe, it is taken ashore and put in piles or spread out for a preliminary drying. (Pl. VI, fig. 2.) If allowed to remain piled up for more than a few hours when fresh, fermentation sets in, as the seed is very damp and soft when gathered, so that almost immediately after it is harvested it is either spread out thinly to dry, or is parched ready for hulling. The parching is at present done by the Indians in a very primitive way, as is shown in Plate VI, fig. 1. The seed is put into a kettle over a slow fire and stirred with a stick until it is roasted so that the hull is brittle enough to be easily broken. Not much more than a half bushel can be parched at a time, and it requires from half an hour to an hour to parch a single lot, and the seed demands constant attention throughout the parching process to keep it from burning. Unless stirred evenly the kernels pop open or become so brittle as to break up badly in the subsequent hulling process. There is a most excellent opportunity for the development of some simple device for the uniform parching of wild-rice seed. The parching is what gives the seed its highly esteemed flavor as a food, and if this operation and the subsequent hulling can be done uniformly the percentage of burned and broken seed will be much less than at present, and, furthermore, the cost of production of the food will be very greatly reduced.

After the seed has been parched it is spread out to cool, and soon after it is hulled. The hulling is at present the most tedious operation in the whole process of preparation. The Indians ordinarily accomplish it by putting about a bushel of the seed into a hole in the ground, lined with cedar staves or burnt clay, and then beating or punching it with heavy sticks. Often three or four men work together on one lot. After the seed has been beaten until the hulls have all been cracked or broken, the grains and hulls are separated by tossing the mixture up into the wind from light birch-bark baskets. After the parching and hulling are finished the grain is sufficiently dry to keep indefinitely. Plate VII shows some wild-rice seed with the hull on, some with the hull removed, and some parched seed, also with the hull removed.

As a food material this parched wild rice is highly esteemed by those who like the "gamy" flavor which it acquires by parching. It is cooked with wild fowl and also used as a breakfast food. For either purpose it should have several preliminary washings in cold water to remove any disagreeable smoky taste. It is also used to a limited extent for making rice cakes. For this purpose it is milled and the darker outer coat is sifted out. When milled without being parched this outer coat is difficult to remove, as it breaks up into small particles that do not readily separate from the flour, so that for all use as food the seed should be first parched and hulled.

The results of chemical analyses given below show approximately the comparative value of wild rice for food purposes. For the table and the statement concerning it the writers are indebted to Dr. C. F. Langworthy, of the Office of Experiment Stations of the Department of Agriculture.

THE FOOD VALUE OF WILD RICE.

The table below shows the chemical composition of wild rice and a number of common cereal grains. Wild rice is usually cooked in a whole or cracked form; therefore the articles selected for purposes of comparison are the whole grains and breakfast foods rather than the ground grains.

Comparison of wild rice and other grains.

	Water.	Protein.	Fat.	Carbohydrates.	Ash.	Fuel value per pound.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Calories.*
Wild rice:						
Whole grain	9.5	12.9	1	75.2	1.4	1,625
Ground	13	10.9	.8	74	1.3	1,740
Parched whole grain	11.2	14.6	.7	72.3	1.2	1,620
Parched and ground	9.5	11.5	.8	76.9	1.3	1,800
Rice, polished	12.3	8	.3	79	.4	1,630
Barley, pearled	11.5	8.5	1.1	77.8	1.1	1,650
Wheat, cracked and crushed	10.1	11.1	1.7	75.5	1.6	1,685
Oats, rolled	7.7	16.7	7.3	66.2	2.1	1,850
Corn meal, unbolted	11.6	8.4	4.7	74	1.3	1,730
Hominy	11.8	8.3	.6	79	.3	1,650
Kafir corn	16.8	6.6	3.8	70.6	2.2	1,595
Buckwheat flour	13.6	6.4	1.2	77.9	.9	1,620

As will be seen, wild rice resembles common cereal grains quite closely in composition. As is the case with wheat, rye, barley, and other grains, the greater portion of the nutritive material consists of carbohydrates, although the amount of protein is proportionately large. Wild rice contains little fat, in this respect resembling rice, barley, and wheat more closely than corn and oats. Judged by its composition and fuel value, it compares very favorably with the common cereal grains. Too much importance should not be placed on the variation in constituents as shown by figures like the above, since it must be remembered that a given constituent in any of the grains may vary to rather wide limits. For instance, the protein in common white rice varies from about 6 to 11 per cent. So few analyses of wild rice are available that but little can be said regarding the range in the proportional amount of the different constituents. Furthermore, little is known of the comparative digestibility of wild rice and other grains. From its extended use by the Indians and others it seems safe to assume that this grain is wholesome, and as said above, analysis shows that it is, like the more common cereals, a nutritious food. So far as can be learned no extended study of the proteids, fats, and carbohydrates of wild rice has been carried on. Some tests which were recently made showed that starch is present in large amounts and in the form which gives a blue color with iodin. No attempt was made to study other members of the carbohydrate group, if such were present. Indications were observed of an enzyme which caused fermentation of the grain when moistened.

When wild rice is soaked in water a peculiar odor is noticeable, recalling that of damp hay. When it is boiled it also possesses a characteristic odor, something like that of boiled barley. The raw grain has a starchy taste, while the cooked grain resembles barley much more than white rice in taste. The flavor is characteristic and is relished by many. When cooked, the wild-rice kernels expand to about two or three times their original size, and except for the bits of dark outer covering ordinarily present the cooked material is of a grayish-white color. In Minnesota and adjacent States where wild rice is best known it is usually eaten as a breakfast cereal, or cooked in much the same manner as ordinary white rice.

ARTIFICIAL PROPAGATION.

When wild-rice seed is to be used for propagating purposes it is now customary to secure it from Indians as soon as possible after it is harvested, and to spread it out thinly over some sort of a floor in the shade and stir it frequently until it is dry. Since it has been extremely difficult to germinate seed so treated, or to secure successful plantings from seed obtained upon the market, there is good reason for believing that it is the present methods of curing seed that are at fault. It was largely for the purpose of determining where this fault lay and how best to remedy it that investigations were instituted. It is true that many of the unsuccessful plantings made during the past owe their failure to the improper selection of the place for planting, due to ignorance regarding the nature of the plant and its environmental requirements; but it is certainly true that the plant may grow in many localities where it is not now found, provided good seed is obtainable.

PREVIOUS FAILURES IN PLANTING.

Some instances are reported where successful plantings have been made, but the greater number have proved entire failures. This is no doubt due to the fact that the seed which is ordinarily obtained from the Indians is treated in such a manner as to kill the germ.

It is allowed to ferment during the curing process or to become too dry, either of which conditions seriously injures its vitality. Practically all attempts to germinate thoroughly dried seed have proved unsuccessful.

PLANTINGS MADE IN 1902.

In order to determine the best methods to be used in curing, storing, and planting the seed a series of plantings was made both in northern Minnesota and at Washington, D. C. The seed was collected fresh and planted in tubs of mud sunk into the muddy bottoms where wild rice naturally grows. The tubs were covered with fine screens to prevent other seeds getting in and to prevent the removal or destruction of the seed planted. These plantings were examined from time to time. No signs of germination were noticed in the autumn immediately following the planting, but at the time the naturally sown seed around the tubs began to grow, in the spring of 1903, the seed in the tubs was found to be germinating freely, thus showing that when the seed is planted in a fresh condition and never allowed to heat or dry it will grow well.

Plantings were also made by Mr. D. W. Hallam, of Dover, N. H., in a number of ponds where wild rice had never grown. In some the seed was planted in the fall of 1902, and in others in the spring of 1903. These ponds were visited the second week in June, 1903, and the plants were found to be growing well in all cases.

STORING SEED.

Mr. Hallam has succeeded in keeping wild rice seed over winter with its vitality uninjured. The following extract from a letter from him under date of April 15, 1903, shows how this was done:

> The wild rice was ordered with instructions to ship as soon as gathered without drying. I received it on the 27th day of October, 1902. The barrel was placed on end in the shade out-of-doors, the head taken out, with about a bushel of seed, and a faucet was put in at the bottom to drain the water. The seed was weighted with a cover, and cold water enough to fill the barrel put in each morning and drained out daily. The barrel was kept full. On the 5th of December ice began to form on the inside of the barrel. Care was taken in adding water so as not to burst the barrel. By the 25th of December there was a frozen mass of ice and seed that filled the barrel. No water was then added until the middle of March, and then only enough to keep the barrel full, for as yet there was quite a mass of ice and seed. Since April began it has been necessary to change the water daily. Our water here is quite cold, 45° to 55° F. I have sent a sample bottle.

The seed received from Mr. Hallam with this letter had germinated and had sprouts from one-half to 1 inch in length when it arrived. Later, a larger quantity of seed, about 2 quarts, was received from Mr. Hallam, of which 75 per cent had germinated.

It seems from the results of the experiments referred to that wild rice can be successfully grown from seed either by sowing the fresh seed as soon as it is gathered or by keeping it in water over the winter and sowing in the spring. In most instances it will no doubt be found more satisfactory to sow in the fall, providing the place sown can be protected from waterfowl and other animals likely to destroy the seed, since such a practice will avoid the trouble of keeping the seed wet during the winter. When the seed is kept in water, either for storage or transportation, the water must be changed frequently or aerated, as fermentation sets in if it is allowed to stand for any length of time.

The seed can be shipped or stored for a short time by packing it in dampened moss or excelsior, and this is a convenient way to prepare it for shipment. It is necessary to separate the seed from the moss or excelsior by layers of cloth, as it can not conveniently be sown when mixed with either. The package, when made up thus for shipment, must not be too thick or too tight to prevent some slight circulation of air, or fermentation will at once set in.

SUGGESTIONS FOR HARVESTING, STORING, AND PLANTING.

(1) Orders should be placed before the harvesting season is commenced, so that the seed may be shipped immediately after it is gathered.

(2) Care should be taken to gather only fully matured seed.

(3) Seed should not be allowed to dry when it is to be used for propagation. For shipment or storage it must be kept wet, with frequent changes of water, or packed in damp moss or excelsior in ventilated packages.

(4) Wherever practicable, autumn planting is recommended.

(5) Care should be used in selecting the place for planting seed to get the proper depth of water—from 1 to 3 feet, with a thick layer of soft mud underneath—and the water should be neither quite stagnant nor too swiftly moving.

DESCRIPTION OF PLATES.

PLATE I. Frontispiece. Field of wild rice just heading out, near Bemidji, Minn. This field is representative of a large area in northern Minnesota and Wisconsin, where the shallow lakes are practically filled with wild-rice plants. This photograph was taken August 28, 1902.

PLATE II. Stems of wild rice. Natural size. Fig. 1.—Portion of the stem of a young plant illustrated in long section to show the pseudonodes and a portion of the leaf-sheath, together with a portion of the stem surrounded by the leaf-sheath, and showing also the ligule and a portion of the leaf-blade with prominent midrib. Fig. 2.—An old stem of wild rice showing the curvature of the base and the root scars in whorls.

PLATE III. Fig. 1.—A staminate flower of wild rice shown in its natural position, with the glumes spread apart and the six empty anthers still retained by the filament. Enlarged seven times. Fig. 2.—Pistillate flower of wild rice, with the outer glume removed to show the lodecules and the stigmas in their natural position, projected on either side of the inner glume. Enlarged seven times.

PLATE IV. Fig. 1.—Pistillate flower of wild rice, showing both the outer and inner glumes below and only the outer glume, with its prominent awn and bristly hairs, above. The illustration shows the flower at the time it is ready for fertilization. The lodecules have expanded and forced the glumes apart below to allow the stigmas to protrude to catch the pollen blown from other plants. Enlarged seven times. Fig. 2.—Panicles of wild rice showing ergot infection. The fungous disease (*Claviceps*, species undetermined) attacks the young ovaries of the wild-rice plant and completely destroys them, producing in their stead irregular, purplish black masses of compact hyphæ which are called sclerotia. Natural size.

PLATE V. Panicles of wild rice. Fig. 1.—Type of the panicle of Potomac wild rice. In this type the branches of the pistillate portion of the panicle are spreading and bear from 17 to 27 spikelets or seeds. About one-fifth natural size. Fig. 2.—Type of the panicle of Minnesota wild rice. In this type the branches of the pistillate portion of the panicle are closely appressed to the main axis and bear from 3 to 7 spikelets or seeds. About one-fourth natural size.

PLATE VI. Fig. 1.—Indian woman parching wild rice. The wild rice is parched in a large kettle over a slow fire and must be stirred continually during the operation to prevent scorching and popping. The birch-bark basket shown in the foreground is the one used for separating the wild-rice seed from the hulls after it has been parched and sufficiently pounded. Fig. 2.—Freshly gathered wild rice drying on a scaffold. The seed in this condition is exceedingly moist and will ferment unless constantly stirred and allowed to dry rapidly.

PLATE VII. Wild-rice seed with the hull on (C), with the hull off (B), and parched (A): the last also with the hull removed. The parched seed shown in the upper portion of the picture is in condition to be used for food. Natural size.

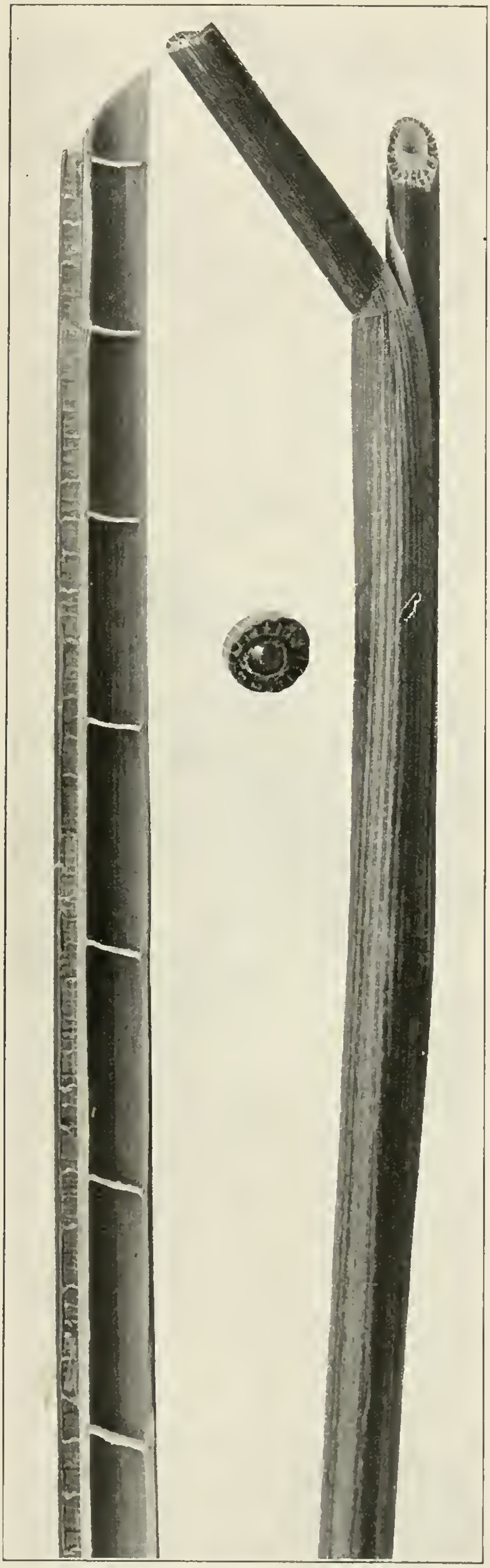

FIG. 1.—YOUNG STEMS OF WILD RICE, SHOWING PSEUDONODES. (NATURAL SIZE.)

FIG. 2.—AN OLD STEM OF WILD RICE, SHOWING THE CURVATURE OF THE BASE. (NATURAL SIZE.)

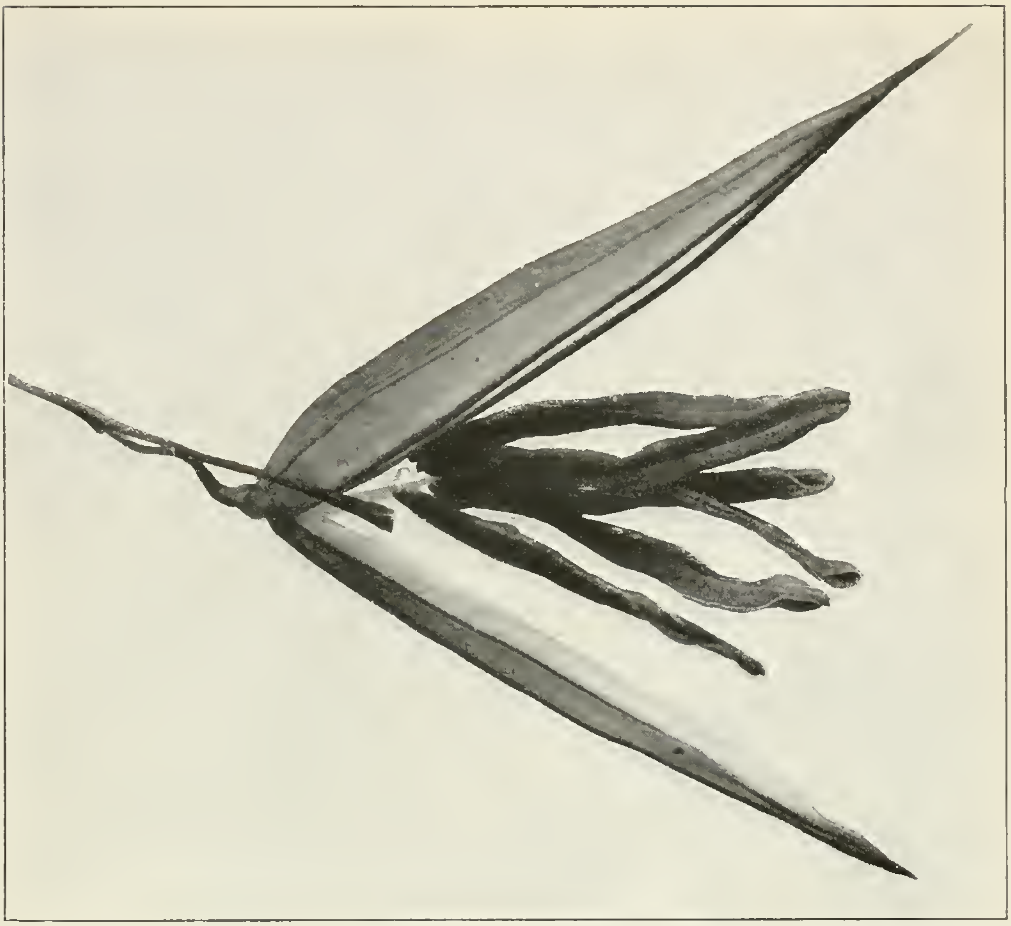

FIG. 1.—A STAMINATE FLOWER OF WILD RICE. (ENLARGED SEVEN TIMES.)

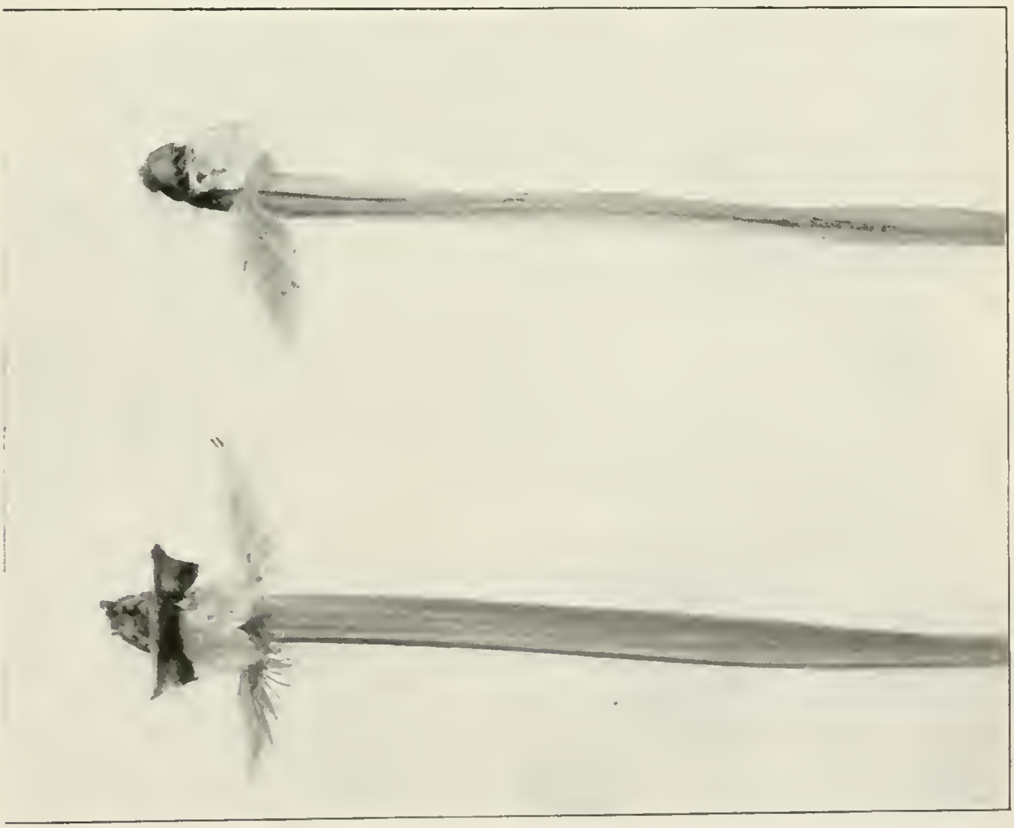

FIG. 2.—A PISTILLATE FLOWER OF WILD RICE, WITH OUTER GLUME REMOVED. (ENLARGED SEVEN TIMES.)

FIG. 1.—A PISTILLATE FLOWER OF WILD RICE. (ENLARGED SEVEN TIMES.)

FIG. 2.—PANICLES OF WILD RICE, SHOWING ERGOT INFECTION. (NATURAL SIZE.)

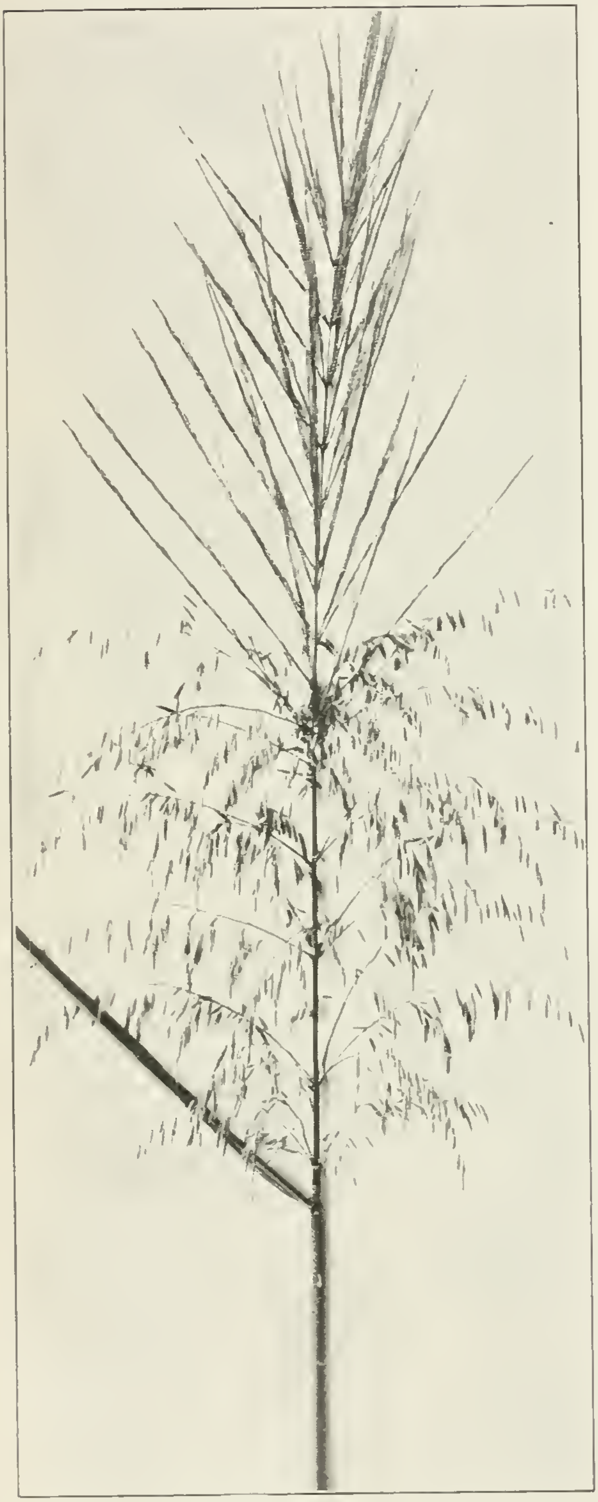

FIG. 1.—TYPE OF THE PANICLE OF POTOMAC WILD RICE.

FIG. 2.—TYPE OF THE PANICLE OF MINNESOTA WILD RICE.

FIG. 1.—INDIAN WOMAN PARCHING WILD RICE.

FIG. 2.—FRESHLY GATHERED WILD RICE DRYING ON A SCAFFOLD.

WILD RICE SEED WITH THE HULL ON (*C*), WITH THE HULL OFF (*B*), AND PARCHED (*A*).
(NATURAL SIZE.)

[Continued from p. 2 of cover.]

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