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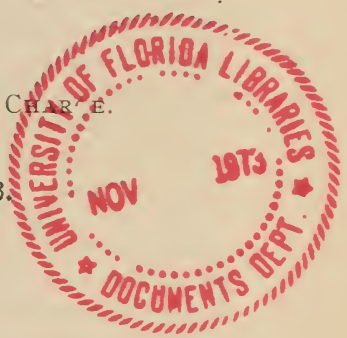
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Hawaii Agricultural Experiment Station, HONOLULU.

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PRESS BULLETIN No. 13.



U.S. DEPOSITORY

RUBBER IN HAWAII.

A comparatively new industry, the cultivation of rubber-producing plants, now engrosses the attention of planters in all tropical lands. There are probably more new areas being planted to rubber than to any other single crop, and much capital formerly invested in coffee, cinchona, tea, cotton and sugar is being diverted to this new industry in the hope that the profits will be greater than are now derived from older established enterprises.

For those interested in new rubber plantations in Hawaii the following notes in regard to the plants which are the chief sources of the world's rubber supply may be of value.¹

In 1900 Africa produced 16,000 tons of rubber, America 31,466 tons, and Asia and Oceanica 2,339 tons, a total of approximately 50,000 tons. The world's production was estimated at 53,887 tons in 1902, 55,603 tons in 1903 and 61,759 tons in 1904. The average price for "Fine Para" in Liverpool has risen from 75 cents per lb. in 1902 to \$1.14 in 1904, and has not been less than \$0.75 since 1895, and has not fallen below \$0.60 since 1877. This rise in price has been due to the greatly increased demand for rubber in the arts and industries without any corresponding increase in the source of supply. The outlook is that the price of rubber will continue to rise until either the price becomes prohibitive thus curtailing demand; or, an artificial substitute for this valuable product is produced synthetically in the chemical laboratory; or, until the world's cul-

¹This is mainly a compilation from the extremely valuable monograph on the rubber plants of the world by Peter Reintgen: "Die Kautschukpflanzen, Eine Wirtschaftsgeographische Studie." Tropenpflanzer, Vol. VI, May, 1905.

tivated rubber plantations begin to yield to the full extent of their capacity.

No extensive new rubber forests are likely to be discovered, although investigators are almost daily adding names to the list of plants from which rubber *may be* secured. New rubbers require much experimentation before their relative commercial value becomes established.

Artificial rubbers may resemble the natural article in some one of its characteristics but none have thus far been produced which have the requisite elasticity.

As to the third solution, while there can be no doubt that cultivated rubber plantations may ultimately supplant the product of the wild trees, it will undoubtedly be a matter of decades rather than years before even a parity between supply and demand is reached. In the meantime the question arises, if we are to plant rubber, to what particular variety shall we pin our faith. A consideration of the climatic conditions under which the various natural rubber producing plants thrive will therefore first be necessary.

AMERICAN SPECIES OF RUBBER PLANTS.

Para Rubber.

In 1904 nearly fifty per cent. of the world's supply of rubber came from the Amazon valley and the major share was classed as "Para." Para rubber is, has been and probably will continue to be the standard of excellence with which all other rubbers are compared. It is in the main derived from a large tree, *Hevea brasiliensis*, Muell. Arg., which grows wild in the tropical forest on the south bank of the Amazon and its tributaries, the Rio Purus, Rio Jurua, Rio Negro, Rio Madeira, and Rio Javary-Iquitos. So far as known, *Hevea brasiliensis* only rarely occurs on the north side of the Amazon, but its place is there taken by other species of *Heveas* which yield rubber of inferior quality and secondary value. *Hevea brasiliensis* is a stately tree often reaching the height of 130 feet with a trunk 3 to 4 feet in diameter, the crown not very large but somewhat dense. The leaf is compound with three oval, sharp-pointed leaflets, dark-green above, bright-green on the under surface and rather prominently nerved. The flowers are small, yellowish-green, and the fruit a 3-celled capsule with 3 seeds as large as hazelnuts.

The trees are sparsely scattered through the tropical jungle over a region as large as Europe, and it is said that the native

rubber collectors consider that a remarkably rich rubber district where the rubber trees average one to the acre. The mean annual temperature of the regions is about 83° F., with an annual range between 73° and 95°. The rainy season begins in October. By January the whole region for 2,000 miles is more or less submerged and the floods do not begin to disappear until June. During the "dry" months, July, August and September, there are frequent thunderstorms. The home of this tree is a hot, steamy, truly tropical, rich alluvial plain, almost under the equator and only slightly elevated above sea level. The tree seldom occurs at elevations greater than 600 feet. Its native habitat, so widely different from the climate of Hawaii, undoubtedly precludes the probability of its successful cultivation in these islands. There are eight or ten other rubber-yielding species of *Hevea*, some of them undescribed by botanists, all native of the upper Amazon valley. While some of these grow at higher elevations and in lands not periodically submerged their total yield is comparatively inconsiderable in quality and amount.

White Rubber. This is produced by a number of species of trees of the genus *Sapium*, native in the north-western portion of the South American continent.

Sapium Tolimense, Hort., is a native of the mountains in South Western Colombia, making its best growth at an altitude of 3700 to 6000 feet. The tree is said to grow with extraordinary rapidity, reaching a height of fifty feet with a trunk one foot in diameter in six years. It will grow at a higher elevation than coffee. The rubber is of very excellent quality. This is certainly a promising variety for introduction into Hawaii.

Sapium verum Hemsl. A forest tree 60 to 75 feet high with a trunk 3 feet in diameter, native to Ecuador and southern Colombia. It reaches its best development at an elevation of 5,500 to 7,500 feet and grows up to 10,000 feet. This tree is the principal source of the "caucho blanco" of Ecuador.

Sapium stylare Muell. Arg. A large forest tree occurring at an elevation of from 3,000 to 6,000 feet on the wet mountain slopes from Venezuela to eastern Ecuador. The mean temperature of the region where it grows ranges from 56° to 61° F.

Other species of *Sapium* growing under truly tropical conditions at lower elevations are *S. tapuri* Ule., *S. eglandulosum* Ule., *S. utile* Preuss, and *S. Marmieri* Huber. The milky sap of the latter is poisonous. These species all require higher temperatures and a greater degree of humidity than is found in Hawaii.

Black Rubber, or Central American Rubber.

The chief source of this rubber is *Castilloa elastica* Cerv. It is a native of the western slope of the Andes of Peru and Ecuador up through Central America to Mexico. The tree grows to the height of 40 to 60 feet in the open, but often reaches 120 to 150 feet in height and 6 feet in diameter in the dense and hot tropical forests. Unlike *Hevea* it will not stand wet feet but requires good drainage. It is never found in wet or swampy localities and grows best at the lower elevations in hot, sheltered inland valleys. In the equatorial belt *Castilloa* occurs up to 2,500 feet but at 15° either side of the equator does not grow well above 1,600 feet. It requires rich alluvial well-drained soils, high temperatures and shelter from winds. The optimum mean annual temperatures for the growth of this tree range from 77° to 82° F. It grows in Mexico where the mean yearly temperature is 72° F. and will stand a much lower one, but as the temperature and humidity decrease the growth of the tree is slower and the yield of rubber rapidly diminishes.

The leaves of *Castilloa elastica* are heart-shaped at the base, entire, bright-green and shining, those of young trees 20 inches long by 7 inches wide, those of old trees 6 to 12 inches long by 2 1-2 to 5 inches wide. The trunk of the tree is wing buttressed at the base. Rubber collectors distinguish 3 varieties depending on the color of the bark and twigs, but botanically all are considered one species.

Castilloa elastica has been widely planted. Five hundred thousand trees of this variety have been planted in the vicinity of Bluefields, Nicaragua, during the last seven years. The first of the planted *Castilloa* forests in Nicaragua has been tapped this year. Six thousand seven-year-old trees yielded 534 pounds of rubber, an average of 1 1-3 ounces per tree. A few of the largest were tapped repeatedly at 2-week intervals without injury and yielded an average equal to that secured at the first tapping. In the regions climatically suited to it *Castilloa* is considered one of the surest and most reliable species in the cultivation of which it is safe to invest the large capital required to plant and care for an artificial forest up to the time when dividends may be expected. However, it is doubtful whether its cultivation should be attempted on more than an experimental scale in Hawaii. Our mean annual temperatures and mean humidity are too low, and also the islands lie within the zone of the trade-winds, and lack the tropical climate of other island groups in equal latitudes.

Ceara Rubber is derived from a small tree usually (in Hawaii) not exceeding 25 to 30 feet in height, *Manihot Glaziowii* Muell. Arg. This tree is a native of southern Brazil. It grows on hot desert-like sandy plains and along the granitic ridges in a region devoid of running streams and with only a sparse cover of desert shrubs and low trees. The mean annual temperature of this region ranges from 82° to 90° F. The rainy season resembles that of Hawaii in that there are only occasional rains during the wet months from November to May, or June, but differs from Hawaii in that the rainy season comes in summer. Although the tree is at its best in this hot desert country it extends inland to the foot-hills, where the rainfall averages about 100 inches and where the night temperatures often fall to 60° F. or less. Like *Castilloa elastica*, the *Ceara* tree requires good drainage and never thrives in wet or swampy soils.

Ceara rubber trees will grow in a very wide range of situations. It makes an extremely rapid growth in Hawaii, thriving from sea level up to 2,500 feet on both the dry and wet sides of all the islands.

The tree is being largely planted in all tropical and sub-tropical countries.

The seeds are about the size of small plum pits and mottled like castor bean seeds. When planted they take a long time to germinate, unless the hard, stony outer coating is filed or abraded. Plant the seed where the tree is to grow either at irregular intervals, if in gulches or along stony ridges or other waste land, or if tillable land is to be used plow and prepare the whole field, or plant in a hole, as is often practised in the case of bananas. The distance apart should be from 6 x 10 to 12 x 15 feet, which would give from 240 to 726 trees per acre. If tillable land is used it will pay to cultivate and fertilize. On gulch, mountainous and waste lands the weeds and grass must be cut out and a space hoed around the foot of each tree as often as necessary.

A number of *Ceara* rubber trees were planted in 1893 on the land now occupied by this Station. A tree standing alone near the Tantalus road in the upper forest in the midst of a clearing, and which has been somewhat spasmodically cared for is about 40 feet high with a trunk 10 inches in diameter. Other trees planted along the trails and absolutely neglected for 12 years, overgrown by lantana and over-shadowed by Eucalyptus are now little more than 12 to 15 feet high with a trunk the size of a man's finger. So it pays to take care of trees even

though common report has it that "no cultivation is required." *Pernambuco Rubber.*

This formerly unimportant but of late years much-talked-of rubber is derived from *Hancornia speciosa* Muell. Arg. It is a medium-sized tree native to the dryer coastal plains and uplands from Venezuela to southern Brazil and from the Atlantic to the eastern foothills of the Andes in Ecuador, Peru and Bolivia. Unlike the *Ceara*, this tree bears rubber in every part of the plant, in the bark, wood, leaves and green fruits. The milky sap which flows from wounds becomes rubber without other treatment than exposure to the air. The flow of milk sap is greatest during the summer months. Although *Hancornia speciosa* is of very slow growth it is being substituted for coffee by many planters in southern Brazil who see only small profits in that business for many years to come.

The tree grows on a great variety of soils, and is easily propagated from cuttings. The leaves are about 2 inches long by 3-4 to 1 inch wide, acute at the base and blunt at the apex. The fragrant white flowers are about 1 inch across. The fruit is a greenish-yellow berry streaked with red, and is edible. The rubber is white and of very good quality.

These species of rubber plants are the chief sources of the American rubber supply. The genera *Hevea*, *Manihot* and *Sapium* belong to the *Euphobiaceae* or Spurge family, well known members of which are the Castor Bean, Tua-Tua and Cassava.

The milky sap which yields the rubber is contained in milk tubes in the inner or growing portion of the bark. *Hancornia* belongs to the botanical family *Apocynaceae*, while *Castilloa* is one of the *Moraceae*, a family including the fig and bread-fruit.

Of the 31,462 tons of rubber exported from South and Central American ports in 1900, 25,500 tons were derived from trees of the genus *Hevea*, 4,700 tons from *Castilloa* and *Sapium* (40% *Sapium* and 60% *Castilloa*) and 1,250 tons *Ceara* and *Pernambuco* rubbers.

AFRICAN RUBBER PLANTS.

The African rubber supply is very largely derived from species of vines of several genera belonging to the botanical order *Apocynaceae*.

Landolphia Hendelottii D. C. is a woody, slow-growing vine native to the dry hot open country from Senegambia to the western Soudan, between 9° and 12° N. latitude. While this is an important source of rubber it is considered unsuited to

cultivation because of its very slow growth. It takes twenty years to attain full maturity.

Landolphia owariensis Beauv., grows in the great tropical forest region of western Africa. About half of the Kongo rubber comes from this vine. A characteristic of this species as yet unexplained is that individual plants growing side by side, and apparently identical, show wide variations in the amount of rubber which they yield,—a fact tending to discourage cultural experiments with this species.

Landolphia Klainei Pierre. Native of the Kongo forests, is considered worthy of cultivation in tropical forest regions because of its great rapidity of growth. It produces a rose-colored rubber of high value.

Landolphia Kirkii Dyer, is the most important rubber-yielding vine of east Africa, extending from the Portuguese possessions to Victoria Nyanza. It is the source of "Mozambique" rubber, which is worth about 3-4 as much as "Para."

There are many other species of *Landolphias* but these are economically the most important.

There are also a number of species of *Clitandra* and *Carpodinus* of greater or less value as rubber-producing plants.

Root rubber is derived from the roots of various herbaceous plants that grow in the open prairies or savannahs in central west Africa. The plants are pulled up by the roots, these cut off, dried in the sun and the bark peeled. The dried bark is pounded in stone mortars until the woody portion is pulverized. The rubber is gathered together, pressed into balls or cakes and is ready for export. About 1,500 tons of root rubber is the average annual crop. It is worth about 60% as much as Para. It is derived from the following species of plants:

Landolphia Thollonii, Dewevre. A woody perennial 6 to 12 inches high with strong horizontal creeping root stocks extending many yards under the surface of the ground. It grows in very dry, sandy soils in regions subject to annual prairie fires, so that while it is undoubtedly an attractive plant for cultural experiments, seeds are not easily obtained. The underground rhizomes are very rich in rubber.

Carpodinus chylorrhiza K. Schum., and *C. gracilis* Stapf, yield a very elastic brownish-red rubber. They are low shrubs 2 to 5 feet high, native of dry, desert regions of central west Africa, little known botanically, but quite important as sources of root-rubber.

Silk-Rubber.

This is derived from the milky sap of an *Apocynaceous* tree *Kickxia elastica* Preuss, native of the tropical regions of west Africa from Kameroun to the Gold Coast. It is considered one of the very best of the recently discovered rubber-producing species. In its home it grows from a few hundred to 3,000 feet above sea level and is said to require about the same climatic conditions as cacao. The milky sap of this tall forest tree is extraordinarily rich in rubber of a superior quality, as high as 58% having been found. A seven-year-old tree is reported by R. Schechter as having yielded 70.5 ounces of rubber which dried to about 60 ounces.

The sap is collected, mixed with 3 to 6 times its volume of water and is then boiled. The rubber rises to the surface, is skimmed off, washed in cold water and then pressed into sausage-shaped masses. Various salts and acids are also used for coagulating the sap without heating it. The tree is a large one, often reaching 100 feet or more in height, and in favorable situations growing with extraordinary rapidity. It does not seem to be especially particular in regard to its soil requirements, but undoubtedly requires high temperatures and a high degree of humidity.

ASIATIC RUBBER PLANTS.

The Asiatic rubbers are derived from both trees and vines.

Assam rubber. This comes from the well-known "Rubber Plant" of the horticulturist, *Ficus elastica* Roxb. This enormous forest tree is a native of the valleys and lower slopes of the whole southern Himalayas, also extending through the countries of southern Asia to Java and the Malayan archipelago. It often grows to a height of 150 to 180 feet, with a clump of trunk-like aerial roots many yards in diameter. The seeds of this tree usually germinate in the top of some nearby tree of a different species, and throw out long aerial roots which at first hang pendant but on reaching the ground themselves throw out feeding roots and increase in diameter until they reach trunk-like proportions. One of these air-roots if destroyed at the base will die below the point of injury but will throw out new aerial roots above, these in turn lengthening until they reach the ground and again throw out feeding roots. In this regard *Ficus elastica* is similar to the Ohia Lehua of the windward forests of Hawaii with its much-branched and many bodied trunks which in the beginning were really the aerial roots of the epiphytic ohia seedling.

In its native habitat this tree grows best at an elevation of from 2,000 to 3,000 feet at from 25° to 27° north latitude, and, nearer the equator, reaching to fully 5,000 feet. The temperature ranges from a winter minimum of 48° to a summer maximum of 92° F., with a yearly mean temperature of 73°. The rainfall of the forest zone where this tree grows ranges from 75 to 100 inches or more. The soils are somewhat rocky, either volcanic or sedimentary. The yield of rubber varies widely. In the total yield from individual trees this species excels all others. P. van Romburgh secured the enormous yield of 405 pounds of rubber from a very old tree in western Java (near Buitenzorg). A 23-year-old tree on an equatorial plantation in Borneo yielded 32 pounds of rubber at its first tapping. In Assam trees averaging 100 feet in height, which had not been tapped for 15 years previously, yielded an average of 10 lbs. of rubber, the next year 4 lbs. and the third year only 1.8 lbs. In New Guinea 8-year-old trees of *Ficus elastica* yielded 5.7 lbs. of rubber within a week. The growth of this tree is somewhat slow in Hawaii; nevertheless I believe that it is one of the most promising rubber trees for plantation culture, especially in such districts as Hilo, Puna, Olaa and Nahiku, where the rainfall is high. *Ficus elastica* will stand low temperatures that are extremely detrimental to the Para and Central American rubber trees.

Practically all the rest of the Asiatic rubbers are derived from vines. It is doubtful whether any of these could be successfully and profitably transplanted to Hawaii.

THE BEST RUBBER TREES FOR HAWAII.

Hawaii with its subtropical rather than truly tropical climate, is limited to a very few species of rubber-producing plants. The most suitable species of those above enumerated are undoubtedly in the order of their importance *Manihot Glaziovii* and *Ficus elastica*. The first of these, the *Ceara* rubber tree, should comprise the larger proportion of all new plantations, because of its extremely rapid growth and early maturity. In laying out a rubber plantation comparatively early returns are desirable. The *Ceara* trees will stand a moderate tapping when three years old, and may be counted on to yield a considerable return in five years.

The Assam rubber tree, *Ficus elastica*, while of much slower growth, yields much more abundantly when it does finally reach a bearing age. This is also true of the Manicoba rubber, *Hancornia speciosa*. The white rubbers, *Sapium Tolimense*, *S. verum* and *S. stylare*, native of high elevations where the climatic

conditions are similar to those of our own mountain slopes, would seem to be promising for experiment, provided seeds can be obtained.

WILD AND CULTIVATED RUBBERS.

Practically all the rubber thus far marketed has been derived from wild trees. The collection of rubber by the native races of all countries has been extremely destructive, in many instances resulting in the extermination of the rubber-producing species over wide areas. This factor alone has had much to do with the rapid rise in value of this article. The discovery of a new rubber-bearing species or of a new forest in some hitherto unexplored region means the rapid destruction of this source of supply, because governmental control of the native rubber gatherers is absolutely impossible, and attempts at restraint or supervision worse than futile. The native collector wants to get as much as he can today, so that he will not have to work tomorrow. Enormous forest trees, perhaps hundreds of years old, are felled or hacked and mutilated so that they soon die and rot, and for his trouble the native secures on an average hardly one per cent. of the total amount of rubber in the bark, but that which he gets costs him only the labor of gathering it. There is no investment of capital. No taxes have been paid on the lands producing the raw material, and there has been no expenditure for labor or permanent improvements and executive management of the enterprise.

In the case of a plantation for the production of rubber on a commercial scale, the points to be considered are not merely the adaptability of certain rubber-bearing species of plants to certain soils and climatic conditions, but it is fully as important to so conduct the enterprise during the first unproductive years that the total capital invested when production finally begins shall not be so large as to preclude the possibility of average dividends. The robbery of cultivated trees after the manner of the native rubber collectors is of course entirely out of the question. A plantation management must evolve methods of gathering rubber in such a manner that the trees will not be destroyed and yet so that they will produce to the very maximum of their capacity. Fungus diseases and insect pests will undoubtedly appear. The question of how much or how little cultivation is necessary will have to be worked out in a practical way. In other words, the cultivation of rubber is an experiment and until it has passed the experimental stage no one knows to what extent it will be profitable.

The outlook is good viewed from the standpoint of an increasing demand for the product.

Conditions in Hawaii are apparently extremely favorable for the cultivation of the *Ceara* trees. One of the newly formed companies have already planted 100,000 seeds of this species, and expect to have half a million trees growing within another two years. If our planters succeed with rubber as they have with sugar, and put into the business as much science, skill and knowledge as they would into any other new enterprise there can be absolutely no question of ultimate success. The planters of Hawaii stand on an equal footing with those of any other of the tropical countries of the world in that the cultivation of rubber is as yet everywhere only an experiment.

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HONOLULU, H. T., July 20, 1905.

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