IMPERIAL INSTITUTE
SERIES OF HANDBOOKS
TO THE
COMMERCIAL RESOURCES
OF THE TROPICS

DUNSTAN

IMPERIAL INSTITUTE HANDBOOKS

COTTON AND OTHER VEGETABLE FIBRES: THEIR PRODUCTION AND UTILISATION

IMPERIAL INSTITUTE SERIES OF HANDBOOKS TO THE COMMERCIAL RESOURCES OF THE TROPICS, WITH SPECIAL REFERENCE TO BRITISH WEST AFRICA

Issued under the authority of the Secretary of State for the Colonies

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THEIR PRODUCTION & UTILISATION

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WITH ILLUSTRATIONS

LONDON
JOHN MURRAY, ALBEMARLE STREET, W.
1919

First Edition . . . . . . *November,* 1917
Second Edition . . . . . *April,* 1919

PREFACE

Among the industrial problems arising from the war, one of the most important is that of the future of our textile industries, especially in relation to the sources from which they derive their raw materials and the possibility of drawing these to a larger extent than was the case before the war from countries within the Empire.

The subject is one that has engaged the close attention of the Imperial Institute for many years, during which it has investigated the possibilities of fibre production in all those British countries which seem to present chances of success. The Institute has given assistance, through experimental investigations conducted in its laboratories and through the supply of technical information, to Governments of the countries concerned, to producers overseas and to merchants and manufacturers at home. A very large amount of information has been collected on questions connected with the experimental production and value of fibres in various countries, much of which has been published in the "Bulletin of the Imperial Institute" and in special reports. In connection with cotton cultivation especially the work of the Imperial Institute has been continuous and has been conducted in intimate association with experimental cultivation overseas, and with the operations of the British Cotton Growing Association. In these subjects of cotton cultivation alone the Institute has issued a large number of special reports.

The increased attention which must shortly be given to extending these sources of supply of cotton and other industrial fibres rendered it desirable that a general summary should be published of the position and prospects of the world's production and utilisation of fibres, and it has been therefore decided to issue the present volume in the Imperial Institute series of Handbooks to the Commercial Resources of the Tropics. Its preparation has been entrusted to Dr. Ernest Goulding, who for many years has been in charge of the Fibre Section of the Scientific and Technical Department of the Imperial Institute.

It will be seen that besides cotton there is room for an increased British production of several important fibres in those countries in which experimental cultivation has already shown that they can be grown with success.

British Africa, and especially East Africa, may become the chief country of production of Sisal hemp hitherto principally obtained from Mexico. Mauritius may be able to produce larger quantities of the similar fibre known as Mauritius hemp, which could also be cultivated in several other countries. India seems likely to be able to meet the increasing demand for jute, in the production of which it holds at present a virtual monopoly. If need be, however, jute could be grown in other countries, of which West Africa is one of the most promising. Among foreign countries Russia and Belgium occupy a similar position with reference to the main production of flax. It is hoped that Ireland may be able to extend her production in the future, whilst Canada is devoting increased attention to the subject. East Africa is a new and promising field for the cultivation of this most useful fibre, which it appears might also be grown in certain parts of India and Egypt.

Of the greatest importance to this country are the prospects of increasing the growth of cotton within the Empire and lessening the uncertainty for the Lancashire cotton industry of so great a dependence on the cotton crop of the United States. It is satisfactory to learn that the Government are now considering the steps which should be taken to consolidate and extend the successful pioneer work of the British Cotton Growing Association in this direction. The problem is one of vital importance and involves economic questions of some difficulty presenting different aspects in the various countries concerned. It also opens up a wide field for assistance from well-conducted plans of experimental investigation in those countries in which it appears that cotton cultivation could be successfully extended.

WYNDHAM R. DUNSTAN.

February, 1917.

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CHAPTER I

INTRODUCTORY

VEGETABLE fibres are in general more or less filamentous or thread-like products, consisting of the tougher and more resistant parts of plants, and possessing considerable strength and flexibility. In virtue of these characteristics, they are of great economic value for the manufacture of durable materials, such as are required for clothing, sacking, floor coverings, and cordage, as well as for paper-making and many other purposes.

They may be classified (1) in accordance with the part of the plant from which they are derived, and (2) according to the economic uses to which they are applied. These two schemes may be referred to as morphological and economic respectively.

Morphological Classification.—The vegetable fibres of commerce are derived from various parts of plants as indicated below :

(1) The hairs borne on the seeds or on the inner walls of the fruit or capsule. Cotton is the principal member of this class, which also includes kapok and other flosses or silk-cottons. Each hair consists of a single, long, narrow cell, free from transverse partitions.

(2) The fibres of which the inner bark or bast tissue of stems is composed. This class is represented by flax, hemp, jute, ramie and related products. The

long strands in which these fibres appear in commerce are not individual cells, but are aggregations of numerous small elongated cells, the so-called ultimate fibres. In the case of flax and hemp, the ultimate fibres are on the average about 1 inch long; those of ramie are much longer and vary from 3 to 12 inches or more, whilst those of jute and its allies are only about 0·1 to 0·2 inch in length.

(3) Fibres which are obtained from leaves and constitute the strengthening or fibro-vascular system of these organs. This class includes the commercial products known as Manila hemp, Sisal hemp, Mauritius hemp, and New Zealand hemp. These fibres, like those of the preceding class, consist of long strands composed of a great number of small, elongated, ultimate fibres, varying in length from 0·05 to 0·25 inch.

(4) The woody fibre of trees which is used in enormous quantities for paper-making and consists of the various elements of which the fibro-vascular tissue of wood is composed.

(5) In this class may be placed a miscellaneous series of products, such as coir, the fibres of which the husk (or mesocarp) of the coconut fruit is composed; piassava, which consists of the ribs of the sheathing leaf-stalks or petioles of various palms; bass or raffia, composed of epidermal strips peeled from the leaves of certain palms; Italian whisk or broom corn, the stems of a certain kind of millet; and Mexican whisk, the roots of a species of grass.

Economic Classification.—A classification of the fibres in accordance with their industrial uses must necessarily be somewhat arbitrary as some of the products are employed for several purposes, and should therefore appear in more than one class. Cotton, for example, is not only used for making textiles, but is also employed for the manufacture of cordage and paper, and for many other purposes.

(1) *Fibres used for the Manufacture of Textiles.*—The principal members of commercial importance belonging to this group are cotton, flax, hemp, ramie, and jute.

(2) *Cordage Fibres.*—In this class are included Manila, Sisal, Mauritius, and New Zealand hemps. (The fibres of Class 1 are also more or less largely used for the manufacture of ropes or twine.)

(3) *Brush and Mat Fibres.*—This class is represented by piassava, coir, palmyra, and certain Agave fibres, such as Mexican fibre (*A. heteracantha*).

(4) *Fibres used as Stuffing Materials in Upholstery.*—Kapok and other flosses or silk-cottons are employed for this purpose.

(5) *Paper-making Materials.*—Almost any fibrous material is capable of being used for paper-making. The wood of various forest trees, especially spruce and poplar, is used extensively for this purpose. Among West African fibres, that of *Adansonia digitata* may be mentioned, which has been used from time to time for the manufacture of a certain class of wrapping paper.

(6) *Miscellaneous.*—In this group may be placed any other fibrous materials not included in the foregoing classes. Reference may be made to bass or raffia, and various products suitable for the manufacture of baskets, fans, hats, and other articles.

Methods of Investigation

The methods of investigating fibres consist of (1) observation of the general characters of the product, including colour, length, softness, lustre, and fineness, (2) microscopical examination, (3) chemical examination, and (4) the measurement of strength and extensibility.

Microscopical Examination.—Microscopical examination is of great value for the identification of fibres. It enables the form and character of the ultimate fibres to be ascertained and facilitates the measurement of their length and diameter. The discussion of this subject is outside the scope of the present work, but a general statement with regard to the form and dimensions of the ultimate fibres of each product dealt with is given in the respective sections. For a fuller account of the microscopical structure of fibres, reference should be made to other treatises, such as Matthews' *Textile Fibres* and Wiesner's *Die Rohstoffe des Pflanzenreichs*. A general method for preparing the ultimate fibres for the measurement of their length and diameter is given for convenience at the end of the following section.

Chemical Examination.—The chief constituent of vegetable fibres is the substance known as cellulose, which is composed of the three elements, carbon, hydrogen, and oxygen, combined in the proportions represented by the formula $C_6H_{10}O_5$. Associated with this substance is a certain amount of water and a small proportion of mineral matter. The cellulose does not exist in fibres as a single definite compound, but rather as a more or less complex product which may be regarded as composed of a typical or true cellulose with certain other groups. The cellulose of fibres may thus be divided into two classes, (1) the pectocelluloses and (2) the lignocelluloses. The pectocelluloses are represented by the fibre substance of cotton, hemp, and flax, and consist of the true or typical cellulose associated with so-called pectic bodies, which can be removed by treatment with alkali. The lignocelluloses form the fibre substance of such products as jute, Manila and Sisal hemps, and wood, and consist of a complex of true cellulose with lignone which itself is a complex of certain simpler groups.

One of the chief objects of the chemical examination of fibres is the determination of the character of the cellulose and the proportion of true cellulose present. The methods usually employed are based on those described by Cross, Bevan, and King in their *Report on Indian Fibres and Fibrous Substances*. The following is a summary of the processes adopted, together with an indication of the manner in which the results are interpreted.

Moisture.—The amount of moisture is determined by drying a specimen at 100—110°C. It is to some extent an index of the susceptibility of the fibre to attack by hydrolytic agents. Textile fibres of the highest class are distinguished by their relatively low moisture content. Owing to the variation of this constituent (1 to 2 per cent.) with changes in the hygroscopic state of the atmosphere, all the other results of analysis are expressed as percentages of the dry fibre.

Ash.—The percentage of ash is determined by completely incinerating the fibre and weighing the residue. An abnormally large percentage of ash usually indicates the presence of mineral impurity introduced during the preparation of the fibre.

a-Hydrolysis.—The fibre is boiled for five minutes with dilute solution of sodium hydroxide (1 per cent. Na_2O), and is then washed free from alkali, dried, and weighed. The loss in weight indicates the amount of substance removed by the solvent action of the alkali.

β-Hydrolysis.—Another portion of the fibre is boiled for an hour with alkali of the same strength. In this case, the loss in weight includes not only the substance removed by the solvent action, but also that rendered soluble by the "degrading" action of the alkali. It is evident, therefore, that the difference between the values obtained on *a*- and *β*-hydrolysis indicates the susceptibility of the actual fibre substance to attack by hot, dilute caustic alkali.

The results yielded by these determinations afford an indication of the ability of the fibre to resist prolonged exposure to moisture and the attack of alkaline liquids with which the fibre may be treated during the processes of manufacture.

Mercerisation.—The fibre is left at the ordinary temperature in contact with concentrated sodium hydroxide solution (33 per cent. Na_2O) for an hour. It is afterwards thoroughly washed with cold water, dried, and the loss of weight determined. The visible effects of this treatment are generally a shrinkage in length of the strands of fibre and the production of a wavy and crinkled outline. The chemical effect consists chiefly of hydration changes. The result of the determination indicates the power of the fibre to withstand the action of strong caustic alkali.

Nitration.—The fibre is submitted to the action of a mixture of equal volumes of concentrated nitric acid (sp. gr. 1·42) and sulphuric acid (sp. gr. 1·84) for one hour at the ordinary temperature. It is then removed, allowed to drain for a few moments, and transferred to a beaker containing a large volume of water. After the fibre has been washed free from the acid, it is heated with water until boiling commences, and is finally dried in the water-oven. The increase in weight is noted. In general, the increase in weight on nitration bears a direct relation to the other chemical constants.

By the process of nitration the celluloses are converted into their nitrates, giving a corresponding increase in weight. The lignocelluloses furnish bright orange-coloured products, whilst those of the pecto-celluloses are colourless, or nearly so.

Cellulose.—The fibre is boiled for five minutes with a solution of dilute sodium hydroxide (1 per cent. Na_2O), is washed free from alkali, and, while still moist, is exposed to the action of chlorine gas for one hour; in some cases a longer exposure is necessary. It is then washed and treated with a solution of sodium sulphite, which is slowly heated until it boils; after two or three minutes' boiling, the product is collected on a calico filter and washed; it is afterwards treated with acetic acid (20 per cent.) and again washed, dried, and weighed.

When the chlorinated fibre is immersed in the sodium sulphite solution, a brilliant purple or crimson coloration is produced if the fibre belongs to the lignocellulose type, whilst in the case of non-lignified fibres, the solution remains practically colourless.

In this method of determining the percentage of cellulose, the non-cellulose substance is rendered soluble and removed, whilst the true cellulose is not attacked. The percentage of true cellulose in a fibre is the most important criterion of its composition and value. A good fibre contains 75 to 80 per cent., or even more.

Acid purification.—The fibre is put into acetic acid (20 per cent.), which is slowly heated until it boils; the fibre is removed, washed first with alcohol and afterwards with water, and then dried and weighed.

The loss in weight is chiefly due to the removal of casual impurities.

Determination of the Length and Diameter of Ultimate Fibres.—A portion of the cellulose, obtained in the manner described above, is placed in dilute acetic acid, teased out with needles, and mounted on a glass slip. The length and diameter of a number of fibres thus separated are determined by means of the microscope, and the maximum, minimum, and average measurements are recorded. These constitute very important factors in the valuation of fibres, and are of assistance in determining their suitability for different manufacturing purposes.

Determination of Strength and Elongation.—The strength of fibres may be determined roughly by hand, but considerable practice is required before it is possible to form an accurate judgment in this way.

To obtain more definite and strictly comparable results, recourse should be had to one of the machines which have been specially designed for this purpose. In order to obtain trustworthy figures, it is necessary that a large number of determinations should be made, and the average calculated.

Among the machines which have been devised for the measurement of strength and elongation under stress (sometimes inaccurately termed elasticity), reference may be made to that of Schopper of Leipzig and that of Reeser and Mackenzie of Philadelphia.

In Schopper's machine, the fibre is clamped in a vertical position between two jaws, the upper of which is attached to one end of a horizontal beam, whilst the lower is connected to a piston which moves in a cylinder, and is lowered or raised by means of hydraulic pressure. A pointer attached to the beam is caused to move over a graduated scale as the tension on the fibre increases. Immediately the fibre breaks, the pointer stops, and thus registers the breaking-strain on the scale. By means of an ingenious arrangement, the elongation undergone by the fibre before breaking is also recorded. This machine can be used for any of the ordinary fibres, and can be employed for the coarser fibres for which the usual form of the Reeser and Mackenzie machine is not adapted.

In the Reeser and Mackenzie machine, the fibre is held in a vertical position with its ends secured in clamps, one of which is fixed and the other attached to the arm of a balance. The other balance arm is then loaded until the fibre breaks; the loading is effected, not by adding weights, but by a screw device which pushes a movable bar along the beam until breaking occurs. A scale allows the strain at the moment of breaking to be read off. The increase in length is ascertained by means of a scale situated at the end of the beam where the fibre is held.

CHAPTER II

COTTON

Cotton is the most important of all fibres. It is employed for the manufacture of the greater part of the clothing material of all nations, and has become vitally necessary to every civilised community. The plant is grown over enormous areas, and its cultivation gives employment to millions of people. The world's commercial supply of cotton in 1913 was estimated by the Department of Commerce of the United States at about 11,127 million pounds; this figure refers only to the amount actually consumed in the cotton mills, and does not include the enormous quantities utilised in the homes of the primitive races of China, India, Asiatic Russia, various parts of Africa, South and Central America, and other regions. The chief countries of production are the United States, which in 1913 contributed about 60·9 per cent. of the world's commercial supply; India, which furnished about 17·1 per cent.; Egypt, about 6·6 per cent.; China, 5·4 per cent.; Russia, 4·5 per cent.; Brazil, 1·9 per cent.; the remaining 3·6 per cent. was supplied by various other countries, including Peru, Mexico, various parts of Africa other than Egypt, Greece, Italy, Turkey, and Indo-China.

Cotton is the raw material of the greatest manufacturing industry of the British Isles. According to the Census of Production (1907), it is estimated that in 1907 the total value of the cotton yarn produced amounted to about £96,000,000, and that of cotton piece goods to about £82,000,000. The number of persons directly employed in the industry was returned as 572,869, of which 220,563 were males and 352,306 females.

The values of the total exports, in the same year, of cotton goods manufactured in the United Kingdom are given in the Board of Trade Returns as follows: yarn, £15,416,971; piece goods, £81,049,207; other cotton manufactures, including such articles as gloves, hosiery, lace, ribbons, and sewing thread, £13,970,914; making a grand total of £110,437,092. In 1913 the grand total amounted to £125,600,951.

The Cotton Plant and its Products

The vegetable fibre, known as cotton, consists of the long hairs which cover the seed of various species of *Gossypium*, a genus of the Malvaceæ, or mallow family. The cotton plant is exceedingly liable to variation, and consequently exists in very many forms. The chief factors which influence this tendency to variation are differences in soil, climate, and environment. Moreover, the plant responds freely to altered conditions of cultivation and also readily undergoes hybridisation. The numerous variations in the characters of the plant which have originated from these several causes have been multiplied by the large interchange of seed which has occurred between the different countries of production, and have rendered it very difficult to determine which are true species and which are only varieties or races. Great confusion has therefore arisen in the determination of the botanical identity of the various cultivated forms. This confusion is illustrated by the fact that whilst Linnaeus recognised only five species of Gossypium, and Parlatore considered that there were seven primary species, Todaro mentioned no less than fifty-four species which he regarded as distinct, the Index Kewensis (1908) enumerates forty-five species, and Watt in his *Wild and Cultivated Cotton Plants of the World* describes forty-two species. Considerable ambiguity has been caused by the indiscriminate manner in which botanical names have been applied. It has often happened that one particular species has been given different names by different botanists. For example, *G. barbadense*, Linn., is regarded by the Index Kewensis as synonymous with *G. acuminatum*, Roxb., *G. frutescens*, Lasteyr., *G. fuscum*, Roxb., *G. glabrum*, Lam., *G. javanicum*, Blume, *G. maritimum*, Tod., *G. peruvianum*, Cav., *G. punctatum*, Schumm. and Thonn., *G. racemosum*, Poir., and *G. vitifolium*, Lam. Further complications have arisen owing to the same name being applied by different botanists to different species. Thus, *G. hirsutum*, Linn., and *G. hirsutum*, Cav., are different species; *G. arboreum*, Linn., *G. arboreum*, Parl., and *G. arboreum*, Vill., are again all different from one another; *G. vitifolium*, Lam., and *G. vitifolium*, Roxb., are also distinct species. It will now be readily conceived that no little difficulty exists with regard to the nomenclature of the ordinary cottons of commerce. In fact it is impossible to determine with any degree of certainty the origin of some of the principal commercial varieties. The ordinary Upland cottons of the United States of America have been regarded by many authorities as derived from *G. herbaceum*, Linn., but are now usually considered as the offspring of *G. hirsutum*, Linn. Some authorities, however, regard these species as identical. Many of the Upland varieties are believed to be derived from hybrids of *G. hirsutum* with Mexican cotton, *G. mexicanum*, Tod., or *G. vitifolium*, Lam. As illustrating the readiness with which the plant undergoes variation, it may be mentioned that more than one hundred distinct races of Upland cottons have been brought into existence by means of well-directed and long-continued efforts to improve the stock.

Sea Island cotton has usually been regarded as *G. barbadense*, Linn., but is considered by Watt to be a hybrid form.

The Egyptian cottons probably cannot be referred to any particular species, but are mostly hybrid forms of *G. barbadense*, Linn., with other species. In general, Egyptian cottons are regarded as *G. barbadense*, Linn., but are sometimes placed under *G. peruvianum*, Cav., which some authorities consider as synonymous with *G. barbadense*, Linn. Fletcher, however, thinks that the present varieties were produced by hybridisation of the Sea Island plant with *G. vitifolium*, Lam.

With reference to the Indian varieties, Professor G. A. Gammie writes : " It is clearly evident that we have at the most only one true species of cotton in India, *Gossypium obtusifolium*, with its two subspecies, *G. arboreum* and *G. herbaceum*." Other botanists, however, regard the Indian cottons as derived from various distinct species, including *G. herbaceum*, *G. neglectum*, *G. Wightianum*, and *G. arboreum*.

Brazilian cotton is generally considered to be the product of *G. brasiliense*, Macf., and Peruvian cotton that of *G. peruvianum*, Cav.

The cotton plant is a perennial shrub or small tree, but is usually grown as an annual. The flowers vary considerably in colour, according to the species. In the case of the typical American Upland variety, the petals are generally white or pale yellow when the flower-bud first opens, but they gradually become darker and redder until the third or fourth day, and then fall to the ground. The flowers of the Sea Island plant and most Egyptian varieties are yellow with crimson spots at the base of the petals. Those of the Indian varieties are mostly yellow with crimson spots, but some of the tree cottons of India and Africa (*Gossypium arboreum*) have deep purplish-red flowers. After the petals have fallen the young fruit remains enveloped in the calyx ; it gradually increases in size, and is known as the " boll." When the boll is ripe, it dehisces by from 3 to 5 valves, exposing the cotton, which, now that the pressure on it is released, rapidly expands and forms a large fluffy mass. As soon as the boll has opened completely and is quite dry, the cotton is ready to be gathered.

The seeds bearing the cotton fibre, forming the product known as " seed-cotton," are collected from the ripe bolls, and the cotton fibre or " lint," after removal from the seeds by the process known as " ginning," constitutes the raw cotton of commerce. Seed-cotton usually consists of about one-third of its weight of cotton fibre and two-thirds of seeds.

AMERICAN COTTON BOLL
Approximately natural size

The seeds of the cotton plant exhibit considerable variation in size, colour, and other characteristics. Some seeds, such as those of the American Upland and Indian varieties, are closely invested with a coating of short, downy hairs, sometimes known as "fuzz," which remains attached to the seed after the removal of the cotton, whilst those of certain other forms, such as the Egyptian and Sea Island varieties, are almost or entirely free from this covering. In general, it may be said that short-stapled cottons have the most fuzzy seed, and that if the staple becomes longer owing to careful selective cultivation, there is a tendency for the seed to become smooth or "naked." The colour of the fuzz is very variable, in some cases being white and in other cases brown, green, or grey.

In the case of the Upland cotton seed of the United States, after the cotton has been separated by ginning, the seeds are generally passed through another machine, known as the "delinter," which takes off any remaining cotton and also removes most of the short, downy hairs or fuzz, the product thus obtained being termed "linters" or "scarto." This process improves the quality of the oil and cake obtained from the seed, facilitates the handling of the seed, retards fermentation during storage, and renders the husks or "hulls" more suitable for use as a subsidiary cattle food. The linters are employed for the manufacture of paper, cheap yarns for carpet-making, and other articles.

Cotton seed contains about 20 per cent. of oil which is of value for soap-making and other purposes. In extracting the oil from Egyptian and other smooth or non-fuzzy varieties, the seeds are crushed without previously removing the hard, outer seed-coats or hulls, but American Upland seeds are usually hulled or decorticated first. This is necessitated by the presence of the fuzz which has escaped the delinter and which, if allowed to remain, deteriorates the quality of both the oil and the oil-cake. The hulls are sometimes ground up and used as a diluent for richer cattle foods, such as cotton-seed meal; they are also largely utilised for paper-making. The oil-cake, or residue remaining after the oil has been expressed, is used extensively as a feeding stuff for cattle. Ginned Upland cotton seed consists approximately of linters, 10 per cent.; hulls, 35·8 per cent.; oil, 20 per cent.; and oil-cake, 34·2 per cent.

According to the length of the individual fibres, cotton is classed commercially as long-, medium-, or short-stapled. The long-stapled cottons are from about 1¼ to 1½ inches or more in length, the medium-stapled about ⅞ to 1 inch, and the short-stapled from ⅜ to ¾ inch.

The principal long-stapled varieties are Sea Island cotton, the Egyptian varieties, and the so-called "improved" American Upland cottons which have been obtained from ordinary Upland types by continuous selection and careful cultivation. The Brazilian and Peruvian cottons vary in length from 1 to 1½ inches, and are therefore either medium- or long-stapled. The chief medium-stapled cottons of commerce are the ordinary American Upland kinds, and the short-stapled class is represented by the East Indian varieties.

Structure and Composition of the Cotton Fibre

The cotton fibre or hair is a single hollow cell without any transverse partition. The hair is of the form of a long, narrow tube or cylinder, the base of which is attached to the seed-coat; its greatest diameter is at a point about one-third of its length from the base. As the hair ripens, it loses its cylindrical form and becomes more or less flattened, and then appears as a narrow, somewhat opaque ribbon or band with slightly thickened, rounded edges. The surface of the hair is smooth and the fibre would therefore be difficult to spin were it not for the fact that it possesses a peculiar characteristic twist. This twist is not present in the early stages, but only becomes developed after the boll has opened and the cotton has been exposed to air and sunlight. The twists are not formed by complete revolutions of the fibre on its central axis, but are sometimes in one direction and sometimes in another; they occur at irregular distances from one another and vary in the degree of convolution. The number of twists in a given length of the fibre is very variable, and is increased by the exercise of care in the cultivation of the plant. The finer the diameter of the fibre, the larger are the number of twists, and hence the twists are most numerous in Sea Island cotton, which is the finest variety yet produced. The presence of the twist imparts a roughness to the fibres which enables them to exert a certain amount of grip on one another, and thus renders it possible for them to be spun into a thread. Unripe cotton consists of thin, transparent fibres with little or no twist. Such fibres are known technically as "dead cotton," and, being very weak and brittle, they break up in the processes of manufacture, thus increasing the amount of waste, and also tending to weaken the yarn or fabric into the composition of which they enter; they also possess the defect of not being able to take dyes satisfactorily. For these reasons the presence of much immature cotton reduces the commercial value of the product.

In chemical composition, cotton consists chiefly (about 90 per cent.) of a comparatively pure form of cellulose, together with about 7 to 8 per cent. of water, 0·4 per cent. of wax and oil, 0·6 per cent. of nitrogenous substances, and 1 per cent. of mineral matter. The wax is present as a thin layer on the surface of the fibre and renders it incapable of absorbing water readily. The oil appears to be identical with that contained in the seed. In the preparation of the so-called absorbent cotton wool which is used for dressing wounds and for similar purposes, the wax and oil are removed by boiling the fibre with a dilute solution of caustic alkali under pressure; the cotton is subsequently washed and treated with bleaching powder and hydrochloric acid, and again washed and dried. The nitrogenous constituents of cotton consist of the remains of the cell protoplasm and allied substances.

When cotton is immersed in a strong solution of caustic soda it undergoes certain remarkable changes, the chief of which is the production of a silky lustre. This phenomenon was discovered by John Mercer in 1844, and has led to results of great commercial importance. The process is now carried out on a very extensive scale under the name of "mercerisation," and is sometimes applied to the yarn and sometimes to the woven fabric. The material is either kept in a state of tension during the operation, or is allowed to shrink in the alkaline liquid and afterwards stretched to its original length before being washed. The process not only produces an exceedingly high lustre on the cotton, but also increases its power of absorbing dyes. The structure of the cotton fibre undergoes alteration; the flattened, twisted tube characteristic of ordinary cotton swells out, and is thus converted into a hollow, cylindrical form. This change in form is accompanied by a decrease in length and also by an increase in tensile strength, mercerised cotton being in some cases as much as 50 per cent. stronger than ordinary cotton. Egyptian cotton generally mercerises better than ordinary American cotton.

When cotton is treated with a mixture of nitric and sulphuric acids, it is converted into nitrocellulose or gun-cotton. This product has the general appearance of ordinary cotton, but is rougher to the touch, grating when rubbed between the fingers, and is inelastic. It explodes on percussion, and burns with a flash. The combustion of gun-cotton is accompanied with the liberation of a large volume of gas, to which the force of the explosion is due. On dissolving nitrocellulose in ether, or a mixture of ether and alcohol, the product known as collodion is obtained, which, when painted on a surface, dries to a thin film. Collodion is employed for closing wounds, for the preparation of photographic plates, for the manufacture of celluloid and other purposes. Gun-cotton is also employed in the manufacture of celluloid.

Cultivation

Cotton is chiefly cultivated in the tropical and semi-tropical parts of the Northern Hemisphere, and, to a much smaller extent, in the Southern Hemisphere. In the Northern Hemisphere the northern limit of cotton cultivation is, in general, the 40th degree of latitude. In the United States of America it does not extend much beyond the 37th parallel, except for a few isolated patches in the States of Kentucky and Missouri. In Europe, however, cotton is grown considerably beyond the 40th degree, the industry being carried on in Eastern Roumelia, on the Southern slopes of the Balkans at 42°40′ latitude, whilst in Central Asia cotton is grown for local consumption as far north as 44°30′. In China and Japan the cultivation does not extend beyond the 40th parallel. In the Southern Hemisphere cotton is not grown nearly so far from the equator as it is in the Northern Hemisphere, the limit being reached at about 25°.

Climate.—The cotton plant requires considerable warmth and sunshine for its satisfactory growth. About six or seven months are occupied in the growing and maturing of the crop, and it is therefore necessary that the climate of the country should be such as to maintain the necessary conditions for this length of time. During the growing period a mean monthly temperature of 65° to 80° F. is desirable. The temperature should be fairly uniform since the plant is very susceptible to sudden changes of temperature, and any check tends to produce premature ripening. The rainfall during this period should be such as to yield a uniform supply of moisture, keeping the soil continuously moist but not wet. The most favourable weather is that which provides much sunshine during the day, and heavy dews or light showers of rain at night. In the earlier periods of growth, moderate showers of rain do not cause any damage, but, as soon as the flowers have opened, dry warm weather must prevail or otherwise the plant suffers considerably and the yield is markedly diminished. Heavy storms or continuous rains are detrimental at any time. After the plant has attained its full size, a lower temperature and a drier condition of the soil are required in order to check vegetative growth and enable the bolls to develop. Under unfavourable conditions, such as lack of sunshine, excessive rain, or early frosts, the crop is liable to be seriously diminished. The cotton plantations should be so situated as not to be exposed to strong winds, since these are liable to injure the plants and also promote rapid evaporation with a consequent drying of the soil.

Soil.—Success in cotton growing depends to a large extent on the character and physical conditions of the soil. The soil should contain a fair amount of sand, which must be finely divided and thoroughly incorporated with the other constituents. Soils which are very rich in humus are unsatisfactory since they lead to the production of too much foliage at the expense of the fruit, and only a small quantity of fibre is formed. Stony or rocky ground is objectionable, whilst stiff, clayey soils are very unsuitable, as they retain too much moisture and clog the roots. As a matter of fact, however, cotton is cultivated with more or less success on soils of almost every description. On very sandy soils, the supply of moisture is usually deficient, the plant is small, the fruit is formed too early, and the yield of cotton is usually poor. In general, it may be said that the most suitable soil is a deep, medium loam with good natural drainage, but capable of retaining sufficient moisture to supply the needs of the plant. The Sea Island cotton of the United States grows best on light, fine-grained, sandy soils containing from about 4 to 8 per cent. of clay, 4 to 6 per cent. of silt, and 75 to 90 per cent. of fine sand. Such soils usually contain about 5 per cent. of moisture. The soils most suitable for the cultivation of Upland varieties contain on an average from 10 to 12 per cent. of moisture during the growing season.

Cultivation and Harvesting.—In considering the system of cultivation, it should be borne in mind that the object of any system is to render assistance to the plant so as to enable it to attain perfect development and thus produce a crop of the best possible quality. If the soil is stiff and hard, it must be thoroughly broken up and loosened so that the root-system, consisting of a long tap-root with numerous branches and ramifications, may be able to penetrate it freely. If it contains insufficient food-materials, recourse must be had to manuring ; weeds, if allowed to grow, rob the plant of food and moisture, and must therefore be eliminated ; if the soil is too sandy, and consequently lacking in moisture, supplies of humus must be added. It is therefore evident that thorough cultivation is of the utmost importance if satisfactory crops are to be produced. The methods of cultivation practised in different countries vary a good deal, and depend to a considerable extent on the local conditions and the varieties grown. For these reasons no attempt will be made to outline a general method of cultivation, but the cultural systems of the United States and Egypt will be reviewed in turn.

Cultivation in the United States

Since the United States of America is the most important country of production, its methods of cultivation will be considered first.

The climatic conditions in the cotton-growing districts of the United States vary widely. The rainfall is, in general, adequate to the needs of the crop, and irrigation is rarely practised, except in Arizona and California. The rainfall usually increases from the spring to the middle of the summer, and then decreases, the autumn being the driest period.

The soils met with in the cotton area are of various types, ranging from heavy clays to light sandy soils. As a rule, the most satisfactory results are obtained on medium grades of loam.

The land is usually ploughed as early in the year as possible to a depth of not less than 8 inches, and sometimes to as much as 10 or 12 inches. The ploughing should not merely turn the soil, but must break it up completely, so as to bring it into a state of fine tilth. Deep ploughing is of value, since it makes the soil more retentive of moisture, and also affords the roots of the cotton plant a wider scope for obtaining nourishment. In order to complete the disintegration of the soil, the ploughing is followed by harrowing, any clods which have been left being thus broken up. The assistance of the roller is sometimes called into requisition for this purpose. When manure is to be applied, it is usually spread over the land and worked in at the first ploughing.

The seed is sown in rows, which are usually about 4 feet apart, although on the lighter kinds of soil they are sometimes only 3½ or 3 feet apart. The distance between the plants in the row varies from about 20 to 24 inches for good soils to 12 to 16 inches for poor soils. The reason for planting fewer plants on a rich soil than on a poor soil is that the former naturally produces larger and heavier plants. When either the variety of cotton or the soil is such as to develop unusually large plants, the rows are widened to as much as 5 feet and the spaces between the plants increased to from 24 to 30 inches. The rows are sometimes marked out by dragging over the land a heavy wooden beam, provided with teeth set at the desired distance from one another. A light plough is run up the markings thus produced, making furrows about 4½ inches deep. The seeds are moistened before sowing in order to favour germination. In some cases the wet seeds are rolled in wood-ashes, lime, or guano, with the object of preventing them from adhering to one another. As soon as the ground has been properly prepared and is warm enough to enable the seeds to germinate, sowing is commenced. Some farmers prefer to manure the ground rather heavily and postpone planting until decidedly warm weather has arrived, but in this case it is safer to plant the seed somewhat deeper than usual. The time of sowing varies a good deal in different parts of the American cotton-belt, but is, in general, between the middle of March and the middle of April. In the smaller plantations, sowing is done by hand, and requires the labour of three persons, one to dig the holes, another to place four or five seeds in each hole, and the third to cover up the seed with the soil. In all the more important undertakings, however, mechanical sowers are employed, by means of which as many as twenty acres can be sown in one day. The seeds are covered with an inch of soil or even with as much as three inches if the land is subject to drought. When a mechanical sower is not used, the seed is covered by means of light hoes. From eight to fifteen days after sowing the young plants begin to appear above the ground. When they are about 3 or 4 inches high, the land requires weeding, and the cultivating plough is brought into action. This implement ploughs the ground only to a depth of 1 or 2 inches, as deeper ploughing is liable to injure the roots of the young cotton plants. After the cultivator has passed up the rows, the ground around the plants is cleaned with hoes. In wet weather all the weeds lying on the surface are picked up by hand and put in heaps at the ends of the rows, as otherwise they would only be transplanted by the cultivator or hoe. Weeding is most important, for unless the weeds are removed the crop is liable to be seriously injured. About a fortnight after the first weeding, the ground is again cleaned and stirred by means of the cultivator in order to break up the surface crust that forms after rain. If rain is frequent, or if weeds persist in growing, the cultivator must be used more often. The plants are now thinned out from each group, leaving only the strongest one in each case, and fresh seeds are sown in places where no plants have survived. A little soil is drawn up round each plant. From this point onward very little work is required. The surface of the ground round the plants is raised by the various hoeings to a height of 3 or 4 inches above the level of the ground between the rows. It is now only necessary to break the surface of the ground occasionally, and to remove the few straggling weeds which have hitherto escaped.

The date at which cotton-picking commences varies in different regions, but it is usually about the middle of August. The season of harvest extends through about three months, October being the most important. Sometimes, however, picking can be continued until the beginning of January, if the ripening of the capsules has not been checked by the cold. If the harvesting is postponed too long, there is a danger that some of the cotton may be beaten to the ground by rain and become discoloured. The pickers carry a sack suspended from the shoulder and open at the mouth, into which the seed-cotton is placed as it is withdrawn from the bolls, the outer case or husk of the capsule being usually left on the plant. The work is done by coloured people of both sexes and all ages, and the quantity that each person gathers in a day naturally varies a good deal, some picking less than 100 lb. a day, whilst others collect as much as from 300 to 350 lb. It is necessary that the cotton should be picked carefully, so as to exclude fragments of capsules or leaves; otherwise the product will be "leafy" and its value consequently diminished.

Owing to the great expense involved in this method of picking by hand, efforts have been made to devise a machine which would pick the cotton automatically. Several such machines have already been invented, and two of the most recent forms are briefly described below.

The Crawford-Elliot cotton-picker consists essentially of a double row of bristle brushes, 1½ inches in diameter and 14 inches long. These brushes are caused to revolve rapidly, and are introduced among the plants and drawn up vertically. The ripe cotton adheres to the brushes, which travel to a receptacle in which the cotton is stripped off, and the operation is repeated. It is claimed that this machine will harvest the cotton at one-fourth of the cost of hand-labour.

The Price-Campbell cotton-picker operates by means of series of spindles, which are either corrugated or bear suitable projections. These spindles are carried in appropriate bearings, fitted into vertical cylinders, a number of which are arranged on an endless band on each side of the machine. The spindles are set in rapid rotation, and when brought into contact with the fibre which has burst from the boll, the latter becomes entwined around them, and is thus collected. The cotton is then detached automatically from the spindles by a special mechanism, and drops into a bag at the rear of the machine. The cotton-picker is mounted on a trolley, which is propelled at a walking pace by means of a petrol engine. This machine gathers about 10 lb. of seed-cotton per minute or 6,000 lb. per day of ten hours. It picks about 90 per cent. of the ripe cotton, and the remaining 10 per cent. is almost completely collected by going over the same rows a second time. The plants do not suffer any damage and neither the flowers nor immature bolls are injured. The main objection to the use of the machine is that it picks more green leaf than is done in picking by hand, but it is stated that an appliance has been devised for attaching to the machine which effects the separation of the leaf from the cotton.

Such a machine, if capable of giving satisfactory results in the ordinary plantations, would overcome the difficulty of obtaining sufficient labour at the picking season, which is the greatest obstacle to the extension of the industry in the United States.

In the United States the second picking is regarded as superior to the first, since the first picking always contains a certain amount of sand and soil which has been beaten up on the lower bolls by the splashing of the rain. In Egypt, however, where the cotton is grown under irrigation, the first picking is always considered the best, and does not suffer this damage.

Cultivation in Egypt

The conditions of the soil and climate in Egypt are very favourable to cotton cultivation, and most of the physical phenomena characteristic of the Nile valley can be readily adapted to the needs of the plant. The success of cotton growing in Lower Egypt is largely due to the hot, moist atmosphere and the elaborate system of irrigation. The rainfall of Egypt is exceedingly small, amounting in average years to only 1·5 inches at Cairo and 7·8 inches at Alexandria. During the whole period of vegetative growth of the cotton plant, little or no rain falls, but the land is fortunately provided with a sufficiency of water by the rise of the Nile and the distribution of its water by means of numerous canals.

The mean annual temperature in the Delta varies from 69·1° F. at Alexandria to 70·3° F. at Cairo. Further up the river, at Assouan, it reaches 80° F. The extremes of temperature observed at Alexandria are 45·1° F. as a minimum and 99·3° F. as a maximum. At Cairo, as would be expected from its greater distance from the sea, the range is wider, the extremes being 36·5° and 109·2° F.

The arable soils of Egypt consist almost entirely of alluvial deposits, but, since the conditions prevailing at their formation were not always the same, the soil does not everywhere present the same physical properties and chemical composition, and the nature of the deposit varies with the depth.

In Upper Egypt, the ancient bed of the river constitutes what is known as the Nile Valley. The river here, during the annual flood, is diverted, by means of flood-level canals, to fill large basins, where the water deposits the alluvium and is then either discharged into a lower-level basin and returned to the Nile or allowed to sink entirely into the soil. By repeated deposits of alluvium the arable land of the Nile Valley has been reclaimed from the desert.

The Delta, on the other hand, has been won from the sea by the rapid deposition caused by the mingling of the river with the salt water. A difference has consequently arisen in the nature of the soil of the two regions. In the Nile Valley, the deposition of the alluvium has been effected by gravitation alone, and the soil is therefore not so rich in clay as is that of the Delta, where the salt of the sea has caused a more rapid precipitation of the argillaceous matter and has also made the land more saline.

The typical soil of the Delta is a heavy, black clay which is difficult to work, but is fertile and well adapted to cotton cultivation. In those districts which yield the best cotton, the soil consists of a mixture of clay and sand, which is always accompanied by a large proportion of vegetable matter, largely due to the growing of Egyptian clover or "berseem" for fodder. The soils of other localities vary from a sandy loam to almost pure sand.

In order to prepare the land for sowing, it is ploughed thoroughly and deeply three or four times and is afterwards thrown into rough ridges from about 32 to 40 inches apart. The land is watered a day or two before sowing, and the seed is sown after having been in water for 24–36 hours. Sometimes, however, the seed is sown dry on dry soil, which is watered directly afterwards. Since the cultivation of cotton is carried on in Egypt by means of irrigation, the plantations must be laid out in such a manner as to facilitate watering. The land is divided into sections by a second series of ridges running at right angles to the ordinary ridges, so that the latter are usually not more than 36 feet long.

The cotton is generally sown between the middle of February and the middle of April, the actual date varying according to the locality. Small holes are made two-thirds up the ridges and 10 to 18 inches apart, and the seeds are planted at a depth of about 3 inches, from ten to twenty being placed in each hole and immediately covered with earth. The plants appear above the soil in from ten to twelve days, according to the weather experienced. The plantations are watered from time to time, from eight to ten waterings being given before the first crops are gathered.

When the young plants have become well established, the fields are hoed in order to destroy weeds and to loosen the soil. Before the first watering, which is given usually about thirty-five days after sowing, the hoeing is sometimes repeated, and the young plants are thinned out, only two typical ones being allowed to remain. The second watering takes place about twenty-five or thirty days after the first, and when the land has become fairly dry, it is again hoed. About three weeks later the fields are watered for the third time, and are subsequently hoed again. The water is now applied more frequently, during June, July, and August two waterings being given each month if possible. During these summer months, however, in which the Nile is low, the amount of water is somewhat limited, and for this reason the frequency of watering is restricted by the Irrigation Department. It is estimated that the amount of water supplied to the cotton plants from the time of sowing until the first crop is gathered is roughly equivalent to a rainfall of 31 to 35 inches.

A brief description may be given here of the manner in which the watering is effected. The water is supplied by the canals of the irrigation system ; it reaches the land by free-flow where the water-level is high, but where the high-water level is below that of the soil the farmers themselves must raise it. This is effected either by various primitive means or by rotatory pumps worked by steam. The water is then distributed throughout the farms by a rough and somewhat leaky system of canals. From the canals the water is conducted round the fields in small ditches ; from these, in turn, it is allowed to run along the furrows separating the ridges on which the cotton grows. The tops of the ridges always remain above the water.

Since the ripening of the cotton bolls is not simultaneous, but extends over a period of two months or more, the whole crop cannot be gathered at once, but is collected in two or even three portions at intervals of about a month. The picking is done by women and children. In the Delta, the first crop is gathered towards the middle of September, but in Upper Egypt, where "Ashmouni" is grown, it is collected at the end of August. In recent years, the time of maturity of the crop has been accelerated by selection, and, in addition, it is now common for 70–80 per cent. of the crop to be gathered in the first picking. The last portion of cotton to be picked is of inferior quality ; it is not mixed with the other portions of the crop, but is sold separately.

Manuring.—Success in cotton cultivation is greatly enhanced by judicious manuring. Cotton is not a very exhaustive crop, since the stems, roots, leaves, and husks of the bolls are usually returned to the soil, the cotton fibre and seed only being actually removed from the land. If the cotton-seed meal is used as a feeding stuff for live-stock on the farm and returned as manure to the land, the demands on the soil are very small, since in this case the only food constituents permanently withdrawn from the soil are those contained in the cotton fibre. The only elements in which a cotton soil is likely to be deficient are nitrogen, phosphorus, and potassium. In addition to these constituents, however, it is necessary that the manure should be such as to increase the amount of humus or organic matter and improve the mechanical condition of the land, and therefore stable manure must form the basis of the applications. This manure should be liberally spread over the land before ploughing for the last time previous to sowing.

The application of soluble nitrogenous manure to the soil is found to be very advantageous to the growth of the young plant, which is unable to obtain the necessary nitrogen rapidly enough from the stable manure, even though the latter may contain quite as much as is theoretically required. If, however, the cotton crop has been preceded by a leguminous crop, such as clover or cowpeas, the addition of soluble nitrogenous manure will probably be unnecessary, since such plants, through the agency of certain bacterial organisms, have the power of assimilating atmospheric nitrogen and enriching the soil in this constituent. In any case, care must be taken that soluble nitrogenous manures are not applied too freely as they tend to produce luxuriant growth, and consequently cause retarded ripening and deficient yield. Nitrate of soda and sulphate of ammonia are the artificial nitrogenous manures best suited to cotton, about 100 lb. of the former or 80 lb. of the latter being the quantity usually applied per acre.

Phosphorus appears to be the chief element required by most cotton soils, and is generally added in the form of superphosphate of lime. It can be used alone, but is usually more effective if employed in conjunction with potash and nitrogen manures. The application of superphosphate is found to check coarse growth, to encourage ripening, and to improve greatly the quality of the fibre. A dressing of from 200 lb. to 500 lb. of this manure is applied per acre.

Potassium is generally less urgently required than nitrogen and phosphorus. It is of comparatively little value if applied alone, but often produces beneficial results when employed in combination with phosphoric and nitrogenous manures. It is usually applied either in the form of kainit or of muriate of potash, from 50 lb. to 200 lb. per acre being used.

Rotation of Crops.—The practice which prevails in many places of planting cotton year after year without intermission is very undesirable, since it generally results in the gradual deterioration and exhaustion of the soil, and consequently diminishes the size and quality of the crop. Such exhaustion, in most cases, however, is only temporary, and if the land is allowed to lie fallow for a few years, it gradually regains its fertility. The reasons underlying the advantages which accrue from a system of rotation of crops are not yet thoroughly understood, but it is certain that much more is involved than the mere withdrawal of the nutritive constituents from the soil, and it is probable that a by no means unimportant part is played by changes induced in the texture of the soil, and by the activity of insects, fungi, and bacteria, both hostile and friendly.

In planning a rotation, it should be remembered that different plants extract the constituents of the soil in different proportions, and that whilst some plants are provided with long roots and obtain their food from the sub-soil, others have shallow, spreading roots and procure their nourishment from the surface layers. Other points to be considered are the effects of the different crops on the growth of weeds and on the presence of insects and other organisms. Bearing these various factors in mind, it is evident that a crop which has long, deeply penetrating roots, such as cotton, should be followed by one having shallow, spreading roots, such as oats or cowpeas, and that one crop should not be immediately followed by another which draws largely on the same ingredients of the soil.

The particular crops to grow in a rotation depend, of course, very largely on the country, its local conditions and requirements. As an example, however, mention may be made of the three-years system which has been found very beneficial in the United States of America. In the first year, maize is grown with cowpeas planted between the rows ; the second year, winter oats followed by cowpeas for hay ; and in the third year, cotton. In Egypt, rotations of two or three years' duration are commonly practised, the cotton crop being almost invariably grown after "berseem" (Egyptian clover) or a fallow, but occasionally after beans.

Acclimatisation and Improvement of Cotton.—There are several means which may be employed in attempting to improve the cotton grown in a country. If there is already a native cotton plant which appears capable of yielding a satisfactory crop, attention should be primarily directed towards the improvement of this variety by careful cultivation and selection of seed. The effect of seed selection on a cotton crop is usually very pronounced, both quality and yield being enhanced. Some improvement can perhaps be achieved by simply picking out large, ripe, well-developed seeds for sowing. Much more, however, may be accomplished by selecting the seed in the field from the most vigorous and prolific plants, or from those plants which show the most desirable qualities. If, for example, it is desired to increase the length of staple, the seeds should be selected from those plants which produce the longest fibre. By repeating this process from year to year, a type of cotton can be established in which the improved qualities will remain fixed so long as care in cultivation and continuous selection of the seed for sowing are practised.

If, however, the country does not possess a cotton plant of a satisfactory type, it is necessary to have recourse to the cultivation and acclimatisation of exotic varieties. In making choice of the cotton to be introduced, consideration must be given in each case to the local conditions of climate and soil and other factors which affect the prospects of success. When a variety of cotton is introduced into a new country, the conditions of its environment are changed, and the constitution of the plant receives more or less of a shock. In order for the plant to adapt itself to the new conditions, it has to overcome certain obstacles, and may become deteriorated in the process. By collecting the seeds of such plants as arrive at maturity and produce a good crop, and sowing these in the following season, the plant will gradually become accustomed to the new conditions, and each successive generation will prove hardier than that preceding it.

It is necessary to make careful observations of the behaviour of a newly introduced variety. The effect of the climate must be noted, the results obtained in different soils and situations should be recorded, the date of flowering and fruiting must be observed, and, especially in the case of cotton, the length of time required by the fruit to ripen. Success in acclimatisation can only be achieved by devoting time and care to the plant.

An improved type of cotton can sometimes be obtained by artificial hybridisation or pollination. Experiments in this direction, however, should only be undertaken by a competent botanist who is prepared to devote much time and study to the hybrids produced, as well as to the offspring of successive generations, with a view to the establishment of fixed types. In order to effect the crossing, the petals and stamens are removed from a flower-bud of one of the plants chosen as the parent forms, leaving the pistil standing alone. The flower is then covered with a paper bag which is fastened round the stem by means of fine wire. An expanded flower of the other parent plant is also covered with a paper bag, and after a day or two is cut off and carried to the flower which has been already treated as described. Both coverings are now removed, and the pistil of the prepared flower is dusted with the pollen of the other. The seed resulting from the cross is carefully planted, and furnishes a number of different forms. From these, a single plant which exhibits the desired qualities is chosen, and the seed from this plant alone is used for further improvement. By selecting the seed of the second generation for sowing, and repeating the process with several succeeding generations, a satisfactory strain may be established. Many experts do not regard artificial hybridisation as a satisfactory method for obtaining improved varieties of cotton, but prefer to take the seed of exceptionally fine plants in the field, sow these, and submit their offspring to the process of seed selection already described.

Efforts are now being made in India, Egypt and other countries to obtain improved varieties of cotton by means of hybridisation and selection experiments, conducted in accordance with the principles established by Mendel.

It is of fundamental importance that such scientific work in breeding experiments should be systematically conducted although immediate results cannot be expected.

Perennial Cottons.—The methods of cultivation described in the foregoing pages refer to the growth of the cotton plant as an annual. A few words must be added with regard to perennial cottons. The cotton plant is naturally of perennial habit, and there is no species known which grows wild in its native country as an annual. There is little doubt that in early times the cottons of India were grown entirely as perennials, and the same is true of those of Egypt, the cotton plant which was introduced into the latter country by Jumel in 1820 being described as a perennial tree (*vide* page 54). As the demand for cotton increased, it was doubtless observed that a more regular crop could be obtained by planting afresh each year, and probably for this reason the perennial forms were gradually replaced by annuals. Moreover, when the plant is cultivated in a climate which during part of the year is hostile to its growth, the plants naturally die off during the unfavourable season and annual planting thus becomes inevitable.

Considerable advantages are gained by growing cotton as an annual. The crop only occupies the ground for six or seven months and can therefore be readily alternated with other crops and a system of rotation established to prevent deterioration of the soil. The early harvesting of the cotton is, moreover, of great importance in checking the spread of pests and diseases. The ground ought to be thoroughly cleared after each crop in order to reduce the risk of disease as far as possible.

At one time it was the custom in the West Indies and other countries to grow perennial stocks and to ratoon the plants or prune them heavily at the end of the season.

In connection with the growth of perennial cotton, reference may be made to certain interesting experiments which are being conducted in Hawaii on the propagation of the plant by cuttings and also by the method of budding. These experiments have already given indications of success.

In some countries, particularly Brazil and Peru, perennial tree-cottons are still grown on a commercial scale. Some of these forms are referred to on pages 69–70.

Diseases of the Cotton Plant

The cotton plant is liable to be affected by numerous diseases. These may be divided into three classes: (1) those which are due to physiological causes, such as deficiencies in certain kinds of nutriment and the consequent weakening of the plant; (2) diseases caused by the attack of fungoid pests; and (3) diseases due to the attack of insect pests.

It is not possible in the present work to deal fully with this subject, but reference will be made to the most important of the diseases, and an indication will be given of the best means of combating them.

Diseases due to Physiological Causes.—Among these may be mentioned mosaic disease or yellow leaf blight, red leaf blight, the shedding of bolls, and angular leaf spot.

Mosaic disease is characterised by yellow spots, which arise on the leaves and occur in a more or less regular order, thus producing a kind of mosaic pattern. As the disease extends, the leaves frequently curl up and fall to the ground. This affection is very often aggravated by the attack of certain fungoid organisms. The most effective remedy is thorough cultivation with a view to improving the physical conditions of the soil. It has been found that the application of kainit to the soil is very beneficial probably owing to its power of binding the particles of soil more closely together and thus enabling it to retain moisture. The same effect can be produced by rolling the land.

The occurrence of *red leaf blight* is manifested by the leaves turning red. The growth of the plant gradually ceases and the leaves fall. This disease is due to the poverty of the soil, and indicates a lack of potash, nitrogen, and probably also of phosphoric acid. The obvious remedy is to supply the necessary food constituents by suitable manuring.

The *shedding of bolls* not uncommonly causes considerable damage in cotton plantations, and is evidently provoked by unfavourable climatic conditions, since it occurs most frequently in times of drought or excessive rainfall.

Angular leaf spot is so called on account of dark angular spots which appear on the leaves. These spots at first present a watery appearance, but later become black and then brown. It is always the less vigorous plants which are attacked by this disease, and it is therefore evident that the method of prevention is to sow good, sound seed and to cultivate carefully so as to give the plant the means of developing satisfactorily.

Fungoid Diseases.—The principal diseases of this nature are anthracnose, wilt or frenching, root rot, cotton leaf blight, mildew, and cotton boll rot.

Anthracnose is due to the fungus known as *Colletotrichum gossypii*. The malady may make its appearance on the bolls, stems, or leaves. When it occurs on the bolls, it first becomes visible as small, dull reddish spots, depressed in the centre. As the spots increase in size, they turn black in the middle whilst the edges remain of a pinkish hue. The pink colour is due to a pigment contained in the spores of the fungus. When the bolls are attacked before they have attained their full size, they frequently become deformed owing to unequal growth. In some cases, the fungus penetrates the seeds, and thus ruins both the seed itself and the cotton attached to it. The disease occurs chiefly in warm, damp weather, during the time that the bolls are developing and ripening.

When the fungus attacks the stem, reddish-brown patches appear on the bark, and as a result of the injury produced the leaves may turn yellow, wither, and fall to the ground. The damage is sometimes serious when the stems of seedlings are attacked, but the effect of the fungus on the stems of well-developed plants is not as a rule very harmful.

No direct remedy has yet been discovered for this malady. The fungus is least prevalent in fields in which the cotton is widely planted and thus enabled to get plenty of light and air. The application of artificial manures containing phosphates and potash renders the plants more hardy and better able to resist the disease. It is desirable in plantations in which the blight has occurred that, after the cotton has been picked, all the cotton-stalks and other remains of the plants should be collected and burned. Cotton should not be grown in such a field during the following year.

Wilt or *frenching* is caused by *Neocosmospora vasinfecta,* a fungus which enters the plant through the roots and gradually grows upwards into the stem and branches. The circulation of the sap is thus interfered with, and the plant is unable to obtain the necessary nutriment. The lower leaves are the first to show signs of the disease. They develop a yellow colour on the under-surface, and gradually die and fall from the plant. In extreme cases, all the leaves fall off and the plant dies. The disease can be recognised by breaking the stem of the plant, when the fibro-vascular tissues are seen to be of a light brown colour.

The only remedy for wilt is the production of a variety capable of resisting the disease. Such resistant forms have been developed by selection in the United States, and it is considered that by this means the Sea Island cotton industry has been saved from extinction.

Root rot is produced by a fungus (*Ozonium* sp.) which attacks not only cotton, but many other plants, including apple trees, the paper-mulberry, and lucerne. The fungus attacks the root and feeds on the material contained in its tissues. The roots gradually wither and decay and are therefore unable to absorb material from the soil and supply the plant with the necessary food and water. The roots of a plant which has succumbed to this disease bear numerous small white excrescences on the surface. The only method of keeping the fungus under control is by means of a system of rotation of crops. Cereal crops are suitable to grow in such a rotation as they are not attacked by the pest. Cotton should not be planted more than once in three or four years in areas which have been infested with root rot.

Cotton leaf blight is a common malady of the cotton plant, but does not often cause much injury. The fungus (*Sphærella gossypina*) usually attacks the older leaves of the plants as well as those which have received some injury affecting their powers of nutrition and assimilation. The disease is not uncommonly found affecting the leaves of plants which have been attacked by other diseases, such as mosaic disease. Leaf blight is characterised by small spots which are white or pale brown at the centre and reddish at the edge. The prevention of this disease may be secured by adopting methods of cultivation calculated to render the environment more suitable for the cotton plant.

Cotton mildew arises on the surface of the leaves in small areas bounded by the veinlets. This fungus (*Ramularia areola*) seems to cause but little damage to the crop, although it is sometimes produced fairly abundantly.

Cotton boll rot, black arm, and *bacterial disease* are all due to the organism known as *Bacterium malvacearum*. Boll rot is first noticeable as a small, dark-brown patch on the boll at a point near the peduncle. If it begins some time before ripening takes place the boll does not open and the immature fibre decays, but if it commences later only a portion of the boll is affected and a certain amount of cotton may be produced.

Insect Pests.—The cotton plant is attacked by a great many different insects, some of the more important of which are the boll-weevil, boll-worms, cotton worms, cutworms, cotton aphis, cotton stainers, and locusts.

Cotton Boll-Weevil.—The most serious insect enemy of the cotton plant is the cotton boll-weevil (*Anthonomus grandis*). Its original home was Mexico, where it caused considerable damage. In 1892 it entered Southern Texas, and since 1894 has travelled at the rate of from forty to seventy miles a year, and is still extending. The pest is now prevalent in the States of Texas, Louisiana, Mississippi, Alabama, Arkansas, Oklahoma, Western Florida, and Georgia. The total area infested was estimated in 1913 as about 296,300 square miles, comprising no less than 47 per cent. of the whole cotton acreage of the United States. The pest has now made such progress that nearly the whole of the cotton-growing area of the country has been invaded. The annual loss occasioned by the depredations of the insect is enormous, but fortunately the pest is confined to Mexico and the United States.

The boll-weevil is a small grey or brownish beetle about one quarter of an inch long. It remains on the cotton plant until the end of the season, and then hibernates, finding a home in a sheltered situation, such as is afforded by hedges and haystacks or by grass, weeds or rubbish lying on the ground. With the advent of spring, the weevil emerges from its winter quarters and again betakes itself to the cotton plant. The female insect eats into the boll and so makes a cavity in which she lays her eggs. The egg hatches in about three days, and a whitish grub or larva emerges, which immediately begins to feed on the tissues of the boll, and consequently destroys the cotton fibre. In from seven to twelve days the larva changes into the pupa or chrysalis. The pupal stage lasts for about three to five days after which the weevil emerges, and about five days later begins the production of another generation. A very large portion of the weevils are killed by the winter frosts, and it is probable that under average conditions not more than 3 per cent. of those which hibernate survive. Large numbers of the weevils are destroyed by insect enemies, many of which are parasitic. When the young fruits which have been infested by the weevil fall to the ground, the larvæ contained in them are very commonly killed by the heat of the sun, and this explains the fact that dry seasons are very inimical to the weevil. In order to control the pest, it is therefore important that the ground should be shaded as little as possible.

Many attempts have been made to destroy the boll-weevil by means of poisons. It was found at first that such methods usually had little effect and that the results did not justify the expense incurred. Recently, however, good results have been found to attend the application of very finely powdered lead arsenate.

The pest can be kept in check by observing the following precautions. At the close of the season, the plants should be uprooted and burned, together with all dead leaves and other refuse which could afford a place for hibernation. Attempts should be made to secure an early crop by sowing early-ripening varieties, planting as early as possible, and applying manures when necessary. A good space should be left between the rows of cotton as well as between the individual plants in the row. Another method which has been recommended is to employ a mechanical device for causing the young infested fruits to fall to the ground so that the larvæ may be destroyed by the heat or by parasites.

Special precautions are now being taken to prevent the introduction of the boll-weevil into other countries in imported seed. In several countries, regulations are in force for the compulsory disinfection of all cotton seed, and in Nyasaland and German East Africa the importation of American seed has been entirely prohibited.

Cotton Boll-Worms.—The American cotton boll-worm (*Chloridea obsoleta* = *Heliothis armiger*), unlike the boll-weevil, feeds not only on cotton, but on many other plants, such as maize, peas, beans, tomatoes, and tobacco. The eggs are usually laid on the under-surface of the leaf. The larva or caterpillar emerges in from two to seven days, and immediately begins to feed near the place where it was hatched. In a few days it reaches a boll, into which it bores. After feeding on this, it migrates to another, and by continuing this course, causes great damage to the crop. Growth is generally completed in about two or three weeks, and the full-grown caterpillar is often as much as 1½ inches in length. It now enters the ground and becomes transformed into the chrysalis or pupa. After about a month the moth emerges, and may often be seen, especially in the evening, darting hither and thither and seeking for a place to deposit its eggs. The boll-worm has many natural enemies, including several parasitic insects and certain bacterial organisms. The woodpecker and other birds pick out the caterpillars from infested maize ears and feed on them.

The pest is found in great numbers on maize plants, and especially on the silky tassels and young ears. When the tassels have passed their edible stage and the maize has begun to harden, the moth seeks another food-plant, such as young cotton. On this fact is based the so-called "trap-crop" method of destroying the insect. It consists in planting maize near the cotton at a period sufficiently late to provide a supply of tassels when the cotton boll is in danger of being attacked by the pest. As soon as the eggs have been deposited, the ears are gathered and destroyed. By planting the maize at different times, several broods of the insect may be trapped, and in this way the pest may to some extent be kept in check.

The use of poisons, especially Paris green and lead arsenate, is recommended for the purpose of lessening the injury caused by the boll-worm. As soon as it is noticed that the moths are becoming numerous in the cotton fields, an application of the poison should be made and should be repeated a week or ten days later. Special care must be taken to distribute the poison as far as possible over all parts of the plant. One method of treating the plant is to mix the Paris green with water in the proportion of one pound to fifty gallons of water and apply it by means of a spraying machine. Another method is to dust the poison on the plants in quantities of about two or three pounds per acre. The powder is placed in a bag of some material which will allow a certain amount to fall through as dust when the bag is shaken. It should be borne in mind that the poison must be employed cautiously as an excess may cause injury to the plants. This plan of attempting to poison the boll-worms is not very commonly adopted in the United States as so many of the insects escape by being hidden in the bolls. Nevertheless, when the pest is abundant and the trap-crop method has been neglected during the early part of the season, the application of Paris green or lead arsenate may save the crop from being entirely destroyed.

The Egyptian cotton boll-worm (*Earias insulana*) is smaller than the American insect but produces a similar effect. This pest has caused much damage to the cotton crops in Egypt and Northern India, and has also produced injury in Northern Nigeria. An allied species (*Earias fabia*) has been observed in India, Ceylon, and Java. In India, the use of "bhindi" (*Hibiscus esculentus*) as a trap-crop has proved beneficial for both species of *Earias*.

The pink boll-worm (*Gelechia gossypiella*) causes great damage to cotton by attacking the seeds in the boll. It is widely distributed in Europe, Asia, and Africa, and has long been a destructive pest in India. A few years ago, the occurrence of the insect was observed in Egypt, where it multiplied so rapidly that in 1913 it caused severe damage to the

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crop. The most effective means of checking its depredations are: (1) to treat all seed at the time of ginning in such a way that the worms protected in the coupled seeds may be destroyed; (2) to remove and burn all bolls found on the cotton plants after the last picking; and (3) to confine all cotton seed remaining in the country after April in buildings fitted with wire netting over the apertures to prevent the emerging moths reaching the cotton fields. Various methods of destroying larvae in seed have been studied, and the following have been found effective: (1) treatment with hot air at 55° to 65° C. for about four minutes; (2) fumigation with carbon disulphide, hydrocyanic acid gas or sulphur dioxide; and (3) immersion in "cyllin" solution (0·1 per cent.) for 24 hours just previous to sowing.*

Cotton Worms.—The American cotton worm (*Alabama argillacea*) is a bluish-green caterpillar with small black spots or black stripes on its back. It devours the cotton leaves, not infrequently stripping the plant bare. The moth usually lays her eggs on the under-surface of the leaf. The eggs hatch in three or four days, and the young larvæ or caterpillars emerge. The larval stage lasts from one to four weeks, and the caterpillar is then transformed into the pupa or chrysalis, which is generally enclosed in a rolled leaf. After a period varying from a week to a month the moth emerges. Each moth lays about 500 eggs, and there are usually five or six generations produced during a single season. The larvæ and eggs are preyed upon by numerous parasitic insects.

The principal method employed for the destruction of the cotton worm is by the application of poisons as already described in connection with the American boll-worm. A favourite way of dusting the plants with Paris green is to place a pole, carrying a sack of the powder at each end, across the back of a horse or mule and then ride the animal between the rows of cotton. By jarring the sacks, a small quantity of

* Of these methods, the hot-air treatment has been accepted as the most practicable, and a law has been promulgated in Egypt requiring all ginneries to instal approved machinery to carry it out.

the powder falls on to the plants, and two rows can thus be dusted simultaneously.

The Egyptian cotton worm (*Prodenia litura*) does much harm to "berseem" (Egyptian clover) and cotton in many districts. The moth lays its eggs on the under-surface of the leaf in batches of two or three hundred. This behaviour is quite different from that of the American cotton worm which lays its eggs on nearly every leaf of the plant and seldom more than three or four on the same leaf. The chrysalis is found in the soil instead of within the folds of a leaf as in the case of the American insect. The following methods are recommended for the prevention of damage by this pest. The soil should be prepared as long as possible before the cotton is sown. The plants should be examined every few days, and all leaves on which eggs have been deposited should be collected and burned. Difficulty was experienced in the past in Egypt in obtaining a sufficient supply of labour for this work, and the Government therefore issued a decree making compulsory the collection and destruction of infested leaves and insisting on the employment of children to do the work at definite periods. This now forms one of the ordinary field operations, and the pest has been much reduced by a law prohibiting the watering after April of berseem, in which the cotton worm lives.

The Indian cotton leaf-roller (*Sylepta derogata*) sometimes causes serious damage. The pest can usually be checked by picking off the affected leaves and burning them, but in serious cases it may be necessary to spray the plants with lead arsenate. This moth has also been observed attacking cotton plants in Southern Nigeria and East Africa.

Cutworms.—The larvæ of certain moths, especially species of *Feltia* and *Agrotis*, eat off the plants just as they come up. They feed at night, and the best method of combating them is to place arsenicated cabbage leaves or grass in places where they have appeared. The larvæ crowd under these for shelter during the day and are thus destroyed. It has been suggested in Egypt that the addition of small quantities of petroleum to the water used for irrigation might assist in the destruction of the pest.

Cotton aphis.—The cotton aphis (*Aphis gossypii*) attacks the young plant and appears in great numbers on the leaf-buds and newly-opened leaves. It sometimes causes considerable damage by sucking the sap from the young leaves, but healthy and rapidly growing plants can usually withstand the attack. The common ladybirds and their larvæ feed upon these insects and thus diminish their numbers to some extent.

The best remedy is the application of soap and kerosene emulsion. This mixture is prepared by dissolving half a pound of soft soap in one gallon of boiling water, and pouring the hot solution into two gallons of kerosene, and beating it up to a creamy liquid. It is then made into a fairly permanent emulsion by forcing it through a fine spray nozzle into another vessel. This emulsion after dilution with ten to twenty times its volume of water is sprayed on to the infested plants.

Cotton stainers.—The large cotton stainers (*Dysdercus* spp.) are found in many countries in which cotton is grown. In the early part of the season, the insects attack the buds or young bolls and suck the sap from them so that they cannot develop satisfactorily. Later generations infest the open bolls, puncture the seed, and stain the cotton with their yellow excrement. The best remedial measure is to place heaps of cotton seed or sugar-cane on the ground to which large numbers of the insects will be attracted and can then be destroyed by the application of kerosene or boiling water.

The lesser cotton stainers (*Oxycarenus* spp.) do not occur in America, but several species have been observed in Africa and two in India. In Egypt, although the pest is chiefly noticeable in its attacks on damaged bolls, it is often the cause of boll-shedding in the early stages of growth, its punctures being apparently toxic. The insects feed on the unripe seeds. The stains on the cotton are not produced during the life of the pest, but are due to some of the insects being crushed in contact with the fibre during the process of ginning. If, however, before the cotton is ginned, it is spread out and exposed to the sunshine the insects take to flight and the staining is thus obviated.

Locusts.—These insects sometimes cause considerable damage by devouring the leaves and young plants and thus rendering replanting necessary. Paris green has been found to be useful in destroying these insects, but the most effective plan is to place upon the ground little heaps of bran mixed with molasses and arsenic.

Leaf-blister mite.—The leaf-blister mite (*Eriophyes gossypii*), although not an insect, is included here for convenience. It is so small as to be invisible to the naked eye, but its attack can be recognised by the leaves becoming curled up and blistered. The blisters or galls are at first of the same colour as the leaf, but later become reddish brown. The mites inhabit these galls and lay their eggs in them. The galls do not appear upon the leaves only but on all parts of the plant except the root. The mite does not usually do much harm to full-grown plants, but sometimes causes serious damage to young plants, thereby diminishing the crop. In order to check this pest the infested leaves should be gathered and burned. The application of sulphur or a mixture of sulphur and lime has also been recommended.

Disinfection of Cotton Seed.—When cotton seed is transported from one locality to another, there is always the danger of diseases or pests being carried in it and thus being introduced into new regions. It is therefore desirable that some method of fumigation or disinfection should be practised in order to avoid the introduction of pests which, if once established, may cause enormous damage and, as a rule, can never be completely exterminated. Disinfection is at present effected chiefly by the following methods, viz. (1) fumigation with hydrogen cyanide, (2) fumigation with carbon disulphide, and (3) treatment with solution of mercuric chloride (corrosive sublimate).

(1) Fumigation with hydrogen cyanide is practised in Uganda. A fumigating chamber has been constructed at Entebbe which is about 8 feet square. It is rendered air-tight by double match-boarding with special paper packed between and is furnished with movable trays for cotton seed. There is a door in the front, and trap-doors are provided in the roof for the escape of the vapour after the fumigation is completed. There are also two small side-doors for the admission of the fumigating materials after the chamber has been closed. The mixture employed consists of potassium cyanide, sulphuric acid and water. The seed is left in contact with the vapour for two or three hours.

(2) In the United States of America, fumigation is usually effected by means of carbon disulphide. Experiments which have been made by the Bureau of Entomology have shown that the destruction of insects, and, in particular, the boll-weevil, is more effectually accomplished by carbon disulphide than by hydrogen cyanide. Both these vapours, however, are unable to penetrate a mass of cotton seed completely unless special measures are adopted for their thorough distribution. This is especially the case with fuzzy seeds which tend to cling together very closely. Apparatus has therefore been specially devised which enables a mixture of carbon disulphide vapour and air to be passed through sacks of the seed in such a manner as to reach every part.

The application of both hydrogen cyanide and carbon disulphide requires the exercise of considerable care as the former is exceedingly poisonous, and the latter is inflammable and liable to cause explosions if carelessly handled.

(3) The Imperial Department of Agriculture in the West Indies recommends the use of mercuric chloride (corrosive sublimate), and this method is said to have been also adopted in some of the German Colonies. The object aimed at in the West Indies is to prevent the spread of diseases, and particularly fungoid diseases, from one island to another. The solution is made by dissolving one part by weight of mercuric

chloride in 1,000 parts of water (or about one ounce in seven gallons). The seeds are soaked for twenty minutes in the solution, care being taken that they are thoroughly wetted. They are then washed in water and spread out in a thin layer to dry on a clean floor or on clean canvas in the shade. Whilst drying, the seeds should be turned over from time to time until they are quite dry. It is necessary to exercise great care in handling the corrosive sublimate on account of its highly poisonous nature.

(4) For the destruction of the larvæ of the pink boll-worms in cotton seed, the Ministry of Agriculture of Egypt advises treatment with hot air at a temperature of 55°-65° C. (*v.* page 40). Special plant has been designed for this purpose in which the heat is regulated automatically.

Preparation of Cotton for the Market

Ginning.—The process of removing the cotton or "lint" from the seed is known as "ginning." In the United States, the cotton used to be picked off the seeds by hand. Very primitive implements have been employed for the purpose in India and are still used in many districts. One of these is a simple wooden roller, worked with the foot on a flat stone slab on which the seed-cotton is placed, the seed being thus pressed out from the cotton. Another is the so-called "churka" gin which, in its simplest form, consists of a rough wooden frame containing two parallel rollers set close together; the upper roller is fixed whilst the lower is rotated by means of a handle. In some forms, the two rollers, which are either both made of wood or one of wood and the other of iron, are both movable and are made to revolve towards each other by means of a crank or wheel at one or both ends. On pressing some of the fibres of the seed-cotton between the rollers and turning the handle, the lint is drawn through and pulled off the seed which, being too large and hard to pass through, remains behind and falls to the ground. Various forms of this machine are found in different parts of India ; the amount of cotton produced by a day's work with it is not more than about five pounds.

It is evident that the cotton industry could not have made great progress, unless such slow and tedious processes of ginning had been replaced by a more rapid and less laborious method. This problem was solved by the invention of the saw-gin by Eli Whitney, which was patented in Washington in 1794.

The saw-gin consists essentially of a series of notched, circular, thin steel discs or "saws" which are fixed on a cylinder. The cylinder revolves in a box, one side of which consists of a grating of steel bars between which the saws rotate. The saws project from ½ to ¾ inch beyond the grating, and grip the fibre as the seed-cotton is fed on to them. As the saws revolve, they pull the cotton off the seed and draw it into the box with them whilst the seeds remain behind, the openings being too narrow to admit them. Immediately beneath the cylinder carrying the saws is a rapidly revolving brush which takes off the lint from the teeth of the saw as it enters the box; a blast of air then carries the cotton into the condenser at the rear of the gin.

There are two kinds of gins in use at the present day, namely, roller-gins and the saw-gin described above. The latter can effect the separation of the lint more rapidly than the former, but is more liable to injure or break the fibres. In the case of the smooth-seeded kinds of cotton, the lint is easily detached, whereas in the fuzzy-seeded varieties, the fibre is very firmly attached to the seed, and considerable force is required to remove it. For these reasons, saw-gins are used for the shorter and fuzzy-seeded varieties such as the American Upland kinds, whilst the longer, finer and smooth-seeded cottons, such as Sea Island and Egyptian, are ginned by means of roller-gins.

Roller-gins are of two kinds. One of these is constructed on the principle of the old Indian "churka" gin and consists essentially of two rollers, which rotate in opposite directions. The cotton is drawn between the rollers, whilst the seed is held back by

From the Collections of the Imperial Institute

GINNING COTTON BY MEANS OF THE CHURKA GIN IN THE TINNEVELLY DISTRICT, MADRAS

From the Collections of the Imperial Institute

GINNING COTTON BY MEANS OF THE MACARTHY SINGLE-ROLLER GIN IN THE NYASALAND PROTECTORATE

means of a steel plate. The second kind of roller gin is that known as the "Macarthy" gin, and is now much more largely used than that just described. In this case the seed-cotton is brought into contact with a revolving roller covered with rough leather (usually walrus- or buffalo-hide). The lint clings to the leather and is thus torn away from the seed; it is then drawn between a steel plate, known as the "doctor knife" (fixed tangentially to the roller and very close to it), and a blade called the "beater," which moves up and down immediately behind the fixed plate and parallel to it. Whilst the fibre is held by the roller, the beater detaches the seed from it. The lint is carried over by the roller and delivered at the other side of the machine, whilst the seeds drop through a grid into a box placed beneath it.

Pressing and Baling.—After the cotton has been ginned, it is collected and made into bales. Great pressure is usually applied in order to reduce the bulk as much as possible before shipment. In olden times, the baling was effected by very simple means, but elaborate machinery is now employed for the purpose.

The bales of different countries vary considerably in appearance, shape, and weight, and can thus be readily distinguished rom one another. The following are the approximate weights of the principal bales which appear in the English market: United States, 500 lb.; Egyptian, 700 lb.; Indian, 400 lb.; Brazilian, from 200 lb. to 260 lb.; Peruvian, between 170 and 200 lb. The bales are usually more or less rectangular in shape. The best made bales are those from India and Egypt, whilst the American bales are badly packed and usually reach their destination in a somewhat dilapidated state. The coverings of the American bales are made of very cheap material and are quite inadequate to protect the fibre. It has been estimated that the amount of loss in transit from the ginnery to the cotton-mill must in many cases exceed 3 per cent. of the original weight of the bale. Complaints have been made repeatedly by spinners with regard to the dirty state in which the cotton arrives, but without much effect. During recent years, however, attempts have been made to introduce better systems into the United States, but hitherto these have only been adopted to a very limited extent.

The cotton exported by the British Cotton Growing Association from West Africa is packed in rectangular bales of 400 lb. each.

CHAPTER III

COTTON PRODUCTION IN THE PRINCIPAL COUNTRIES AND THE CHIEF COMMERCIAL VARIETIES

Production in the United States of America

It is generally supposed that the cotton plant is not indigenous to the United States but was probably introduced from Mexico. It is stated that the plant was not grown as a fibre crop until about 1620, and its cultivation underwent comparatively little development until nearly two hundred years later. The industry may be said to date from 1794, the year in which Eli Whitney's saw-gin was patented (see page 46). From that time forward the production and exports increased at a remarkable rate, as is shown in the following table, which gives the approximate quantities of ginned cotton for 1790, and each tenth year thereafter as well as for the years 1911–1915. The only serious check which the industry encountered was during the Civil War of 1861–1865.

Year.	*Production.* Millions of lb.	*Total Exports.* Millions of lb.
1790 . . .	$1\frac{1}{2}$	
1800 . . .	35	20
1810 . . .	85	59
1820 . . .	160	120
1830 . . .	350	265
1840 . . .	644	506
1850 . . .	1,021	886
1860 . . .	1,836	294

Year.	*Production.* Millions of lb.	*Total Exports.* Millions of lb
1870	1,924	1,399
1880	3,039	2,130
1890	4,093	2,797
1900	4,846	3,238
1910	5,552	3,852
1911	7,506	5,159
1912	6,556	4,471
1913	6,772	4,480
1914	7,719	4,332
1915	5,354	3,978

The area devoted to cotton each year in the United States is about 33 million acres. The principal States in which the crop is grown are South Carolina, Georgia and Alabama on the east of the Mississippi, and the eastern half of Texas on the west of the river. The acreage planted has increased during recent years, owing partly to the development of new regions in Oklahoma and Western Texas, but more largely to extension within the so-called cotton belt. There are vast areas of land which could be rendered suitable for the crop, but the scarcity of labour is a formidable obstacle to progress in this direction. It is considered, however, that the production could be greatly increased on the lands at present cultivated by the more general use of manures, by the employment of modern agricultural machinery for preparing the soil, and by more diversified farming.

The average yield of ginned cotton in the United States is about 200 lb. per acre.

The crop consists mainly of Upland varieties, the amount of Sea Island cotton produced being less than one per cent. of the whole.

The consumption of cotton in the mills of the United States has undergone a steady increase and at the present time is growing more rapidly than the production of the raw material. The following table records the approximate quantities used in 1830, and each tenth year subsequently, and also in 1912, 1913 and 1914.

Year.	Millions of lb.	Year.	Millions of lb
1830	62	1890	1,245
1840	118	1900	1,701
1850	202	1910	2,168
1860	403	1912	2,737
1870	490	1913	2,760
1880	892	1914	2,830

British cotton manufacturers rely mainly on the United States for supplies of their raw material, and the extended utilisation of the product in that country has therefore caused considerable anxiety to them as well as to the cotton manufacturers of other European countries. This has given rise to efforts to create new sources of supply in order to render the industry less dependent on the American crop (compare page 76).

The quantities of cotton imported into the United Kingdom from the United States in certain specified years are given below :

Year.	Millions of lb.	Year.	Millions of lb.
1875	841	1908	1,589
1880	1,224	1909	1,640
1885	1,051	1910	1,470
1890	1,317	1911	1,682
1895	1,395	1912	2,165
1900	1,365	1913	1,585
1905	1,734	1914	1,284
1907	1,756	1915	2,022

The United States Department of Agriculture are conducting important investigations with the object of improving the cotton both in yield and quality. Efforts are also being made to encourage farmers to adopt scientific methods of cultivation, and educational work is being carried on in order to increase their knowledge of the best ways of preparing and manuring the soil, of selecting the seed, and of establishing rotations of crops.

In view of the large quantities of Egyptian cotton now being imported into the United States, the

Department of Agriculture have endeavoured to grow these varieties in Arizona and South-eastern California. As a result of prolonged acclimatisation and breeding experiments, several different types have been derived from the original stock of seed imported from Egypt. Two forms, the so-called "Yuma" and "Somerton" varieties, are as distinct in the characters of the plants and fibre as some of the newer varieties which have originated from "Mitafifi" cotton in Egypt (see page 58). Two other varieties, termed "Pima" and "Gila," have been described recently. The Yuma form is now grown on a commercial scale in the Salt River Valley, but the Somerton variety has been abandoned because, although it produced excellent fibre, it was late in maturing and developed vegetative branches to an excessive extent. The cotton yielded by these new varieties is regarded as equal in all respects to Egyptian cotton of corresponding grades.

American Varieties

Sea Island.—The Sea Island variety is the longest and finest cotton the world produces, and is therefore the most valuable. The fibre varies in length from $1\frac{5}{8}$ to $2\frac{1}{4}$ inches, and has a diameter of about 0·00064 inch. It is soft and silky and has an excellent lustre. This cotton is grown chiefly in the Sea Islands of South Carolina and in the interior of Georgia and Florida, and is now being cultivated extensively in the West Indies. The cotton grown in South Carolina is of the finest quality but is almost equalled by that now produced in the West Indies. The length of staple of these products is usually about 2 inches or more, whereas the cotton grown in Georgia and Florida is generally from $1\frac{5}{8}$ to $1\frac{7}{8}$ inches long. In order to maintain the quality of Sea Island cotton, it is necessary that seed selection should be practised or the crop will deteriorate. The plant needs special attention since it is more delicate than other varieties. It requires a rather sandy soil, and a well-regulated supply of water. The regions in the interior of

Photograph by W. N. Sands, F.L.S.

PICKING SEA ISLAND COTTON IN ST. VINCENT

Photograph by W. N. Sands, F.L.S.

A FIELD OF FINE SEA ISLAND COTTON, ST. VINCENT

Georgia and Florida which grow Sea Island cotton also produce considerable quantities of Upland cotton, and for this reason the plant undergoes hybridisation and rapidly degenerates into the ordinary Upland type; it is therefore necessary to obtain new seed frequently from the coast districts.

Sea Island cotton is used in commerce for spinning only the finest and best yarns. The quantity of this cotton produced is comparatively small; in 1913 about 30 million pounds were produced in the United States and, roughly, 3 million pounds in the West Indies.

American Upland Cottons.—These cottons are used to a very much larger extent than any other varieties, and are employed for the manufacture of yarns of medium quality. They are produced in enormous quantities in the United States, the crop amounting on the average to about 6,000 million pounds or approximately two-thirds of the total production of the world. The fibre varies in length from 0·7 to 1·1 inches, and in average diameter from 0·00076 to 0·00078 inch. The seeds are usually covered with fuzz or down, differing in this respect from those of the Sea Island variety, which are black and smooth. In the Liverpool market, the American Upland cottons are classed as "ordinary," "good ordinary," "low middling," "middling," "good middling," "fully good middling," and "middling fair," these grades being indicated by the abbreviations "Ord.," "G.O." "L.M," "Mid.," "G.M.," "F.G.M.," and "M.F." The "ordinary" grade is the poorest class of cotton; the quality of the other grades improves in the order in which they are quoted, "middling fair" being the best of all.

Long-stapled or "improved" Upland varieties.—The occurrence of long-stapled Upland cottons in the United States of America and their special value were first brought to general notice about thirty years ago, and from that time onward considerable efforts have been made to cultivate and improve the existing forms as well as to produce new varieties of similar character. These cottons are grown chiefly in the alluvial delta region of Mississippi and Louisiana, and to a smaller extent in the valley lands of the Red River in Louisiana and Texas.

"Improved" Upland cottons usually have a length of between $1\frac{1}{4}$ and $1\frac{3}{4}$ inches, and a diameter intermediate between those of Egyptian and ordinary Upland.

They are generally less lustrous than Egyptian cottons, and are not so well adapted to the mercerising process. There are a great many varieties of these cottons, among which may be mentioned, "Allen's Long Staple," "Bates' Big Boll," "Black Rattler," "Bohemian," "Commander," "Cook's Long Staple," "Culpepper," "Excelsior," "Griffin's Improved," "Hawkins' Improved," "Moon," "Peterkin," "Richmond," "Russell's Big Boll," "Shine's Early Prolific," "Sunflower," and "Truitt's Big Boll." Most of these forms were obtained by the selection of choice individual plants in fields of ordinary Upland cotton. It has sometimes been supposed that some of the "improved" varieties were produced by hybridisation of ordinary Upland with Sea Island cotton, but it is now generally considered that most, if not all, of the present forms were derived directly from Upland cottons by methods of selection. Many attempts have been made to obtain new varieties by the artificial hybridisation of Sea Island and Upland cottons, but there is apparently no authentic instance on record of such a hybrid ever having been definitely fixed.

Production in Egypt

Although it is sometimes stated that cotton has been grown in Egypt for many centuries, there does not appear to be any authentic record of its cultivation prior to 1583. The crop was not cultivated systematically until about 1820. In this year, Jumel, a French engineer, called attention to a tree-cotton growing in gardens, and suggested that the cultivation should be extended and an effort made to replace the forms then existing by superior varieties. About the same time, a change was made in the irrigation system of Lower Egypt, and large areas were thus rendered available for the crop. The industry developed very rapidly, and at the present time cotton is the most important agricultural product of the country.

The average area under cultivation during the three years 1910–11, 1911–12, and 1912–13 amounted to rather more than 1¾ million acres. In the same period, about 78 per cent. of the total area planted was situated in Lower Egypt, and 22 per cent. in Upper Egypt. There is little prospect of any great extension of the area in Lower Egypt, but in Upper Egypt the land devoted to the crop has been gradually increasing and will probably continue to do so. The area planted in Upper Egypt was 91,716 acres in 1898–99, 280,745 acres in 1908–9, and 398,057 acres in 1912–13.

In the following table, statistics are given of the total area planted, the total production of cotton, and the yield per acre during the years 1895–6 to 1912–13.

Year.	Area planted.	Total Production.	Yield.	Average yield for triennial periods.
	Acres.	*lb.*	*lb. per acre.*	*lb. per acre.*
1895–6	1,035,649	522,600,500	505	
1896–7	1,090,677	582,362,400	534	531
1897–8	1,171,021	648,146,400	553	
1898–9	1,163,870	553,572,200	476	
1899–1900	1,197,133	644,780,300	539	479
1900–1	1,277,071	538,384,300	422	
1901–2	1,297,380	630,939,700	486	
1902–3	1,324,153	578,332,150	437	463
1903–4	1,383,145	644,711,200	466	
1904–5	1,491,304	625,339,300	419	
1905–6	1,626,133	590,326,400	363	407
1906–7	1,563,530	688,336,400	440	
1907–8	1,664,147	716,594,500	431	
1908–9	1,702,751	668,698,900	392	374
1909–10	1,657,743	495,323,000	299	
1910–11	1,705,029	750,158,800	440	
1911–12	1,776,268	735,367,800	414	424
1912–13	1,787,244	746,135,700	417	

It will be observed that although the area under cultivation has undergone a gradual increase, the amount of cotton produced has not increased to a corresponding extent. The diminution in yield from 1895–6 to 1909–10 is shown very clearly by the figures expressing the average yield per acre during the triennial periods. The decreased yield was unfortunately accompanied by a deterioration in the quality of the crop. This decline appears to have been due to processes which have been in operation for a long time but have only been brought prominently to notice during recent years. The subject is of the utmost importance to the welfare of Egypt, and has been investigated by a Government Commission. The degeneration is attributed chiefly to over-watering and insufficient drainage, accompanied by a consequent rise in the level of the water in the sub-soil with the result that the country is becoming water-logged. When it is remembered that the root of the cotton plant cannot grow under such conditions, or that a root growing in good soil dies when the soil becomes permanently charged with water, it is obvious that satisfactory results cannot possibly be expected in these circumstances. The primary cause of the rise of the water-table is due to the construction of barrages and regulators designed to raise the level of the water in the river and the canals so as to lessen the amount of lift required for pouring the water on to the land. The defect of this system of irrigation is that water is supplied to land which did not receive it previously during the summer months whilst no provision is made for the removal of the excess. The methods recommended to overcome the difficulty are to check the tendency of the growers to over-irrigate, to keep the water in the canals at as low a level as possible, to provide catch-drains, where necessary, along both sides of the canals to prevent infiltration, and to extend and improve the whole drainage system of the country. Extensive schemes are under consideration.

Other causes which have been regarded as contributory to the decline in yield and quality are the deterioration of the soil, the degeneration of the plant, the ravages of insect pests, especially the cotton- and boll-worms, insufficient manuring, and the cultivation of the crop by some growers in a biennial instead of a triennial rotation. All these factors are being taken into serious consideration by the Department of Agriculture, and efforts are being made to effect improvements in every direction.

The great increase in the crop of 1910–11 was due to the fact that the Nile flood was late and the period of over-watering consequently delayed. A prolonged spell of warm weather in the autumn promoted evaporation from the soil and thus prevented the soil from being too wet. Similar conditions prevailed in the following year. In 1913, the Nile flood was the lowest on record and a large crop was again produced. These results confirm the view that the excess of subsoil water was the principal cause of the fall in the yield during earlier years, culminating in the disastrous crop of 1909–10.

The distribution of the Egyptian cotton crop is illustrated by the following figures giving the quantities (thousands of lb.) exported to different countries in the year 1913: United Kingdom, 296,794; United States, 66,712; Germany, 65,878; France, 65,001; Russia, 59,420; Austria-Hungary, 42,795; Switzerland, 27,141; Italy, 26,340; Japan, 17,776; Spain, 15,812; Belgium, 2,437; Holland, 2,400; British India, 713; Portugal, 700; Turkey, 442; Greece, 191; other countries, 92; total, 690,644.

Egyptian Varieties

The cotton introduced into cultivation in 1820 was grown for many years under the name of "Jumel." "Sea Island" cotton was introduced in 1822, and was cultivated until about 1860. Brazilian cotton is also said to have been grown from about 1827 onwards. In course of time, from these various forms the "Ashmouni" cotton plant was evolved, which is the oldest of the varieties now cultivated in Egypt. The principal varieties grown at the present time are "Ashmouni," "Sakellaridis," "Mitafifi," "Nubari," "Abassi," "Yannovitch," and "Assili." The approximate percentage of the total cotton area devoted to each of these varieties in 1913–1917 is stated in the following table.

	1913.	1914.	1915.	1916.	1917.
Mitafifi . .	36·2	26·6	17·7	8·5	5·7
Assili . .	3·8	7·6	4·2	4·0	2·2
Yannovitch .	10·1	7·3	2·4	0·3	0·1
Nubari . .	11·7	14·9	9·0	3·8	2·3
Sakellaridis .	14·3	22·5	46·2	62·3	67·6
Abassi . .	2·2	0·7	0·6	0·2	0·3
Ashmouni .	20·7	20·2	19·5	20·8	21·6
Other varieties .	1·0	0·2	0·4	0·1	0·2
	100	100	100	100	100

Ashmouni.—This variety, though at first grown in the Delta, is now cultivated almost exclusively in certain districts of Upper Egypt, where it occupies about 94 per cent. of the total cotton area. Ashmouni cotton is of a brownish colour, but not so dark as Mitafifi; it is less valuable than the latter and does not yield such fine qualities of lint. The fibre is 1·1—1·3 inches long, and 0·00076 inch in average diameter.

Mitafifi.—The Mitafifi or Afifi variety was derived from Ashmouni, and was first cultivated in 1883. The seeds of this plant are black and bear small green tufts at their ends. The fibre is fine, very strong, from 1·3 to 1·5 inches long, and has an average diameter of 0·00072 inch; it is of a pale reddish-brown colour. It is said that the colour is affected considerably by salt, the cotton plants grown on the more saline soils furnishing the darkest-coloured cotton. Mitafifi cotton gives a high yield, ranging, on average soils, from 500 to 600 lb. per acre.

Nubari.—This variety, probably obtained by selection from Mitafifi, has come into favour during recent years, and has been grown on an extensive scale. The cotton is of excellent staple, and closely resembles a high grade of Mitafifi. The fibre is 1·3—1·6 inches long, and has an average diameter of 0·00068 inch.

Abassi.—This variety was obtained by selection from Zafiri, which, in turn, was obtained from Mitafifi. It was introduced into general cultivation in 1893. The fibre is white, and in this respect differs from all the other varieties cultivated in Egypt at the present time. The cotton is fine, silky, 1·2—1·4 inches long, 0·00067 inch in average diameter, and of good strength; it is not so strong, however, as Mitafifi cotton, and is more difficult to gin. During the last few years, the cultivation of this variety has rapidly declined.

Yannovitch.—This cotton has been cultivated since the year 1897. It is supposed to have originated by hybridisation from Mitafifi and Gallini (a variety, closely resembling Sea Island, which was formerly cultivated). The best qualities are grown on the salt soils of the northern part of the Delta. The fibre is very strong, 1·4—1·6 inches long, 0·00068 inch in average diameter, and is one of the finest and most silky of the Egyptian cottons.

Sakellaridis.—This variety has been recently established, and is known by the name of the discoverer, M. Sakellaridis, who found the plant some years ago among a crop of Mitafifi cotton. This form matures earlier than Mitafifi, and was grown in 1910 on a fairly large scale in the Gharbia and Sharqia Provinces. Since that year it has become increasingly popular, and now occupies 93 per cent. of the total cotton area of Lower Egypt. The cotton is soft, silky, lustrous, cream-coloured with a faintly reddish tinge, of good strength, 1·4—1·7 inches long, and has an average diameter of 0·00062 inch. The fibre is superior to that of Yannovitch, being finer, more silky, and slightly paler in colour.

Assil Afifi.—A superior type of Mitafifi cotton has been produced by selection and is known by the name of " Assili " (meaning " of pure original strain ") or " Assil Afifi."

Hindi.—Reference must be made to the so-called "Hindi" cotton of Egypt, isolated plants of which are commonly to be seen in fields of the Mitafifi variety. The plant can be readily distinguished by the fact that the boll opens in four, or sometimes five, valves instead of three. It bears a white, somewhat coarse, inferior fibre, about one inch long, the presence of which in Mitafifi cotton diminishes the value of the crop. In 1904, the Khedivial Agricultural Society introduced the practice of examining the Mitafifi seed for sowing and picking out all the long and naked seeds, bearing long spikes at the pointed ends, which were supposed to be of the Hindi variety. Experiments have shown, however, that on planting such seeds an excessively large proportion of plants of the Hindi type is not produced. Moreover, it has been found recently that some plants which produce ordinary brown Mitafifi cotton bear long, naked, spiked seeds of the Hindi type, and that ordinary Mitafifi plants are sometimes produced from the so-called Hindi seed. These facts evidently indicate that such plants are hybrid forms, and it is obvious that cotton possessing the Hindi character can never be completely eradicated by picking out the naked spiked seeds. The production of a pure Mitafifi cotton could only be effected by starting afresh with a few perfect plants, and sowing only the seed derived from these, and thus in course of time a thoroughly good cotton would be established. Great improvement has resulted from the action of the Department of Agriculture in distributing better seed to the cultivators.

Uses of Egyptian Cotton

The special characteristics of Egyptian cotton render it particularly useful for certain purposes for which American Upland and other varieties are unsuitable. It is better adapted to the mercerising process (see page 16) than any other cotton, and its high lustre and excellent capacity for dyes give it great value for mixing with silk and for the production of fabrics with a brilliant finish. The brown colour of the Mitafifi, Nubari and some other types permits of their use in the manufacture of certain articles, such as underclothing, curtains and embroidery in which the natural écru shade is preferred. Egyptian cotton is also of great utility for the production of strong sewing thread, as well as for cycle and motor tyres and other purposes for which strength and smoothness are required.

Production in India

The cultivation of cotton and its manufacture into textiles have probably been practised in India for three or four thousand years.

Indian cotton was almost exclusively employed in the British cotton industry during its early years, but was subsequently replaced by the product of the United States. Much of the fibre formerly produced in India was of a high grade but, during the last hundred years or so, a striking change has taken place. Short-stapled, inferior varieties have appeared, and have become distributed throughout the country, whilst the cultivation of the finer kinds has become greatly restricted. The causes of this change may be briefly indicated. In the first place, the introduction of ginning machinery led the growers in many localities to cease their custom of ginning their cotton by hand and reserving their seed for sowing, and induced them to send their produce to the public ginning factories, with the result that cotton from widely separated areas was mixed together. The seed was returned to the cultivators without discrimination, and thus it commonly happened to be quite unfitted for the particular locality in which it was to be sown. Another cause was the change of market consequent on the English spinners having abandoned Indian cotton in favour of that of the United States. The demand for the finer staples decreased, and a market for the inferior kinds was found in Japan, Germany, and India itself, where numerous mills were erected for the production of coarse materials from short-stapled cotton. The result was that Indian growers were unable to obtain higher prices for long-stapled than for short-stapled kinds, and, as the latter gave the larger yields, they naturally turned their attention to these in preference to the superior varieties. The advantages of the short-stapled cottons to the cultivators may be illustrated by reference to the substitution of Jari cotton for the superior Hinganghat or Bani variety in the Central Provinces and Berar (see page 67). The inferiority of Indian cotton is also largely due to impoverishment of the soil and lack of care in cultivation. In some parts of the country, the seed is sown broadcast on land which has had little or no preparation and is rarely, if ever, weeded. In the best cotton tracts, however, such as the Broach and Surat districts of Bombay, a more careful system of cultivation is adopted.

The cottons produced in India at the present day are chiefly short-stapled, varying in length from 0·5 inch to 1 inch, and for this reason are to a great extent unsuitable for the Lancashire industry as the machinery now in general use is particularly adapted for cottons of longer staple, especially those of the American Upland varieties which have a length of one inch or more. The Indian cottons are, in general, somewhat coarse, the average diameter being about 0·00084 inch.

The area devoted to cotton in India and the production and exports during the years 1905–6 to 1913–14 are stated below.

Year.	*Area.**	*Production.†*	*Exports.*
	Acres.	Thousands of lb.	Thousands of lb.
1905–6 . . .	13,099,359	1,667,380	828,748
1906–7 . . .	13,771,268	1,941,832	828,894
1907–8 . . .	13,909,269	1,512,960	958,947
1908–9 . . .	12,958,974	1,680,060	761,422
1909–10 . . .	13,172,188	1,971,200	1,004,421
1910–11 . . .	14,447,690	1,721,200	972,877
1911–12 . . .	14,568,189	1,601,600	820,795
1912–13 . . .	14,138,497	1,825,200	826,281
1913–14 . . .	15,844,363	2,318,800	1,190,147

* In British India, excluding Native States. † Including crop of certain Native States.

About one-half of the crop is used in the Indian mills, whilst the remainder is distributed to Japan, Germany and other countries as shown by the following statement of exports during 1913–14.

Exports of Raw Cotton (1913–14)

	Quantity. Thousands of lb.	*Value.* £.
Japan	539,567	12,934,223
Germany	189,064	4,001,628
Belgium	126,905	2,820,900
Italy	95,041	2,121,177
Austria-Hungary	83,669	1,949,417
France	58,718	1,349,195
United Kingdom	43,110	957,351
Spain	18,696	448,502
Hong Kong	12,273	264,895
China (exclusive of Hong Kong and Macao)	9,487	226,065
Other countries	13,617	288,302
Total	1,190,147	27,361,655

The comparative magnitude of the cotton growing industry in different parts of India is shown by the following estimates (page 64) of the areas under cultivation and the quantities produced in the various Provinces and Native States in the year 1913–14.

Numerous attempts have been made from time to time to effect an improvement in the cottons of India. Strenuous efforts were made by the East India Company in 1829–1841, and were especially directed to the introduction and acclimatisation of American Upland varieties. These endeavours, however, met with failure everywhere except in Dharwar. In this district a New Orleans variety was established, which is regarded as the parent form of the cotton now produced (compare pages 67–68).

Province.	*Estimated Area.*	*Estimated Production.*
	Acres.	Thousands of lb.
Bombay (including Native States) . .	7,100,000	628,800
Central Provinces and Berar . . .	4,715,000	384,400
Hyderabad State	3,653,000	160,000
Madras	2,593,000	205,200
Punjab (including Native States) . .	2,053,000	237,600
United Provinces	1,586,000	193,600
Central India States	1,426,000	109,200
Rajputana States	470,000	52,800
Sind (including Native States) . .	332,000	53,200
Burma	288,000	20,000
Mysore	93,000	6,400
Bihar and Orissa	86,000	7,600
North-West Frontier Province . .	59,000	5,600
Bengal	51,000	5,200
Ajmer-Merwara	57,000	6,000
Assam	33,000	4,800
Total	24,595,000	2,080,400

The average yield of cotton per acre in India during 1913–14 thus amounted to about 85 lb.

During recent years, the problem of improving the Indian staple has received a large amount of attention at the hands of the Agricultural Departments. The work has included a survey and classification of the indigenous varieties, the introduction of exotic varieties, the production of new forms by hybridisation, the improvement of the native varieties by seed selection, and endeavours to improve the methods of cultivation. At the present time it is considered that, in most districts, progress can be best ensured by improving the indigenous cottons, rather than by attempting the acclimatisation of foreign kinds. The following are some of the principal results that have been achieved.

In Bombay a hybrid of the local Coompta variety has been produced which gives a higher yield of cotton than the ordinary Coompta, and realises better prices. The Broach variety has been introduced into the Southern Mahratta country with great success, and has proved more profitable to the growers than the local Coompta; the cultivation of this cotton has recently undergone considerable extension, Cambodia cotton, an American Upland variety, introduced from Cochin-China, is being grown in several localities, and yields a very satisfactory crop.

Cambodia cotton is also being cultivated successfully in various districts of the Madras Presidency, and the crop is now known in the Liverpool market as "Tinnevelly American." Much attention has been devoted to the ordinary Tinnevelly cotton, which includes the forms termed "Karunganni" and "Uppam." The lint of the former is much superior to that of the latter, and an effort has therefore been made to ensure that Karunganni should become the principal form cultivated. Large quantities of pure Karunganni seed have been grown and distributed with the result that this form now predominates throughout the southern portion of the Tinnevelly District. Attempts have been made to improve Northerns cotton in the Kurnul district, and a pure variety is being cultivated and the seed distributed to growers.

Promising results have been obtained with Egyptian and American varieties in the Jamrao Canal district of Sind.

In the Central Provinces and Berar, the different types of cotton which constitute the Jari mixture have been isolated and submitted to selection, in order to ascertain which is the best form to grow for the production of seed for distribution to the cultivators. It has been found that an acclimatised American Upland cotton, known as "Buri," gives a better yield per acre and a larger proportion of lint on ginning than the local Jari, and is resistant to wilt-disease; this variety is now being extensively grown. Buri cotton also promises to be very successful in the Punjab.

In the United Provinces, an American variety is being grown successfully in the Cawnpore area. Buri cotton has also been introduced, and has given promising results.

Indian Varieties

The Indian cottons of commerce are classed in certain well-defined groups, distinguished by peculiarities of staple, and designated according to the localities in which they are grown. These groups or commercial varieties must not be regarded as uniform cottons, derived from a particular variety of plant, as, although some of them are the product of a single, definite botanical form, others are produced by mixtures of different varieties or races.

The cottons may be roughly divided into early and late varieties. The early cottons are sown from March to June, and require five or six months to reach maturity. They include Bengals, Oomras and Hinganghat. These varieties are grown on light soils, and are usually produced as mixed crops showing wide variations in character. The late cottons are sown from June to October and yield a crop in about eight or nine months. They include Broach, Dholleras, Coomptas, Dharwars, Westerns, Coconadas, and Tinnevellys. These varieties are usually found on deep, moisture-retaining, black, loamy soils, and are generally grown as comparatively pure crops of uniform character and consisting of definite races of the cotton plant.

Bengals.—These cottons are grown chiefly in the Punjab, United Provinces, Rajputana, and parts of Central India, but comparatively little is produced in Bengal. They are the shortest and coarsest varieties grown in India, and are often depreciated by the presence of yellow stains. The fibre is harsh, somewhat weak, and from about $\frac{1}{2}$ inch to $\frac{5}{8}$ inch long.

Oomras.—This cotton derives its name from the town of Oomraoti or Amraoti in Berar, and is mainly produced in the Province of Berar, and in the Khandesh, Barsi, and Ahmednagar districts of the Bombay Presidency. The quality of the cotton from the different regions varies to some extent, and the group is therefore divided into Oomras proper, Belati, Khandesh, and Barsi and Nagar. Oomras proper, the chief cotton of Berar, is white, soft, strong, $\frac{3}{4}$—$\frac{7}{8}$ inch long, but is usually rather leafy, *i.e.*, contaminated with fragments of broken capsules. Belati cotton is grown in Berar and the Central Provinces; it is white, rather harsh and weak, and shorter than Oomras proper. Khandesh consists of a mixture of at least three varieties, and is therefore of irregular length (with an average of $\frac{5}{8}$—$\frac{3}{4}$ inch), and is inferior to Oomras proper; it is usually somewhat leafy. Barsi and Nagar cottons are, on the whole, of good staple, but usually contain a good deal of "leaf."

Hinganghat or **Bani** is a superior cotton, produced in the valley of the Wardha in the Central Provinces. The quality of this cotton has undergone considerable deterioration, and its cultivation has declined owing to its gradual replacement by a mixture of varieties known as "Jari" which yields a coarse, short lint. Jari cotton ripens earlier than the Bani variety, is hardier and less liable to disease or injury from rain, and gives a larger yield; it is therefore preferred by the Indian ryots. Hinganghat cotton is a white, lustrous, strong cotton, with a length of about 1 inch.

Broach, the best and finest of the indigenous cottons of India, is peculiar to the Southern Gujerat Province of the Bombay Presidency. It is of good colour and lustre, soft, silky, fine, and $\frac{7}{8}$—1 inch long. The staple resembles that of American Upland cottons, but unfortunately the variety has undergone serious degeneration and some of the finest forms have entirely disappeared.

Dholleras.—This cotton is produced principally in the Native States of Kathiawar, and in smaller quantities in parts of Northern Gujerat and in the Cambay and Baroda States. The product is fine, soft, fairly strong, and $\frac{7}{8}$—1 inch long, but is usually dirty and leafy. The quality of this cotton has been impaired by the admixture of short-stapled varieties.

Coomptas.—This variety is grown in the Dharwar district and somewhat resembles Broach, but is of darker colour and less lustrous. It is soft, fine, strong, and about 1 inch long, but is often dirty.

Dharwars.—This cotton is said to be an American variety, derived originally from New Orleans seed, which has become acclimatised in the Dharwar district. It was at one time of excellent quality, and although it has undergone considerable deterioration it is still one of the best grades of Indian cotton. Saw-ginned Dharwar is of good white colour, very clean, soft, fine, silky, strong, and $\frac{3}{4}$—1 inch long.

Westerns.—These forms are produced in the Madras Presidency, and to a smaller extent in parts of the Bombay Presidency and the Nizam's Territory. They are of strong, coarse staple, $\frac{3}{4}$—$\frac{7}{8}$ inch long, but are generally dirty and leafy. Westerns are subdivided into Westerns proper and Northerns, the former coming from the country north of Bellary and Kurnul, and the latter from Cuddapah and Kurnul. Westerns proper are fairly white, but dull and rough. Northerns are silkier than Westerns, but possess a slightly red tinge.

Coconadas.—This variety is grown chiefly in the Kistna district of the Madras Presidency, and to some extent in the Godaveri and Nellore districts. The cotton is fairly long, strong, and silky, but has a reddish-brown tint; it is used for the manufacture of lace and dyed goods.

Salems or **Coimbatores.**—This is an acclimatised exotic variety, derived from Bourbon seed, which is grown in the east of Coimbatore, Madras Presidency. The cotton was at one time of excellent quality, but has greatly deteriorated, and is now very poor, short, coarse, rough and weak. It is said to be employed for adulterating the superior Tinnevelly cotton.

Tinnevelly.—This cotton is grown in Tinnevelly, Madura, Trichinopoly, Tanjore, and South Arcot. It is very white, has a silky lustre, and is fine, soft, strong and remarkably clean. This variety is used by English manufacturers for spinning in admixture with American cotton, and is one of the few Indian cottons suitable for the purpose.

Peru and Peruvian Varieties

The greater part of the Peruvian cotton crop is grown in the deep alluvial soil of the river-valleys situated between the sea-coast and the Andes. This region is characterised by an exceedingly low rainfall, and elaborate systems of irrigation have therefore been established. During recent years the production has undergone a rapid increase. The crop amounted to about 13 million lb. in 1899, and to nearly 48 million lb. in 1909. The approximate production in 1910 was estimated at 47 million lb.; in 1911, 48 million lb.; in 1912, 53 million lb.; and in 1913, 71 million lb. The principal varieties grown are "smooth" Peruvian and "rough" Peruvian, but Sea Island and Egyptian Mitafifi are also cultivated to a small extent. The relative quantities of these cottons produced may be illustrated by reference to the amounts exported in 1909, which were approximately as follows: "smooth" Peruvian, 30,800,000 lb.; "rough" Peruvian, 15,700,000 lb.; and Sea Island and Mitafifi, 1,200,000 lb.

"Smooth" Peruvian.—This cotton is of a type resembling ordinary American Upland, and is about 1·0—1·2 inches long. The plants are usually cut down after the first crop has been picked and allowed to grow up again for a second year. The second year's crop is about 20 per cent. smaller than that of the first year.

"Rough" Peruvian.—This is the true Peruvian cotton (*Gossypium peruvianum*) and is only grown in the regions of Piura and Ica, where the atmosphere is warmer and drier than in other parts of the coastal area. The plants are grown as perennials, being left in the ground for five or six years. The seeds of this tree-cotton are of the "kidney" type, being thus designated owing to those in each cell of the boll being united to one another to form a kidney-shaped mass. The fibre is of a peculiarly harsh and crinkly nature, and is much prized for these qualities which render it particularly suitable for spinning in conjunction with wool. It meets with a ready demand in all wool manufacturing countries, and especially in the United Kingdom. The cotton is of good length, viz. about 1¼—1½ inches, and has an average diameter of about 0·00078 inch.

Brazil and Brazilian Varieties

Although there is a very extensive area in Brazil which is admirably adapted to cotton cultivation, the crop is at present chiefly grown in the valley of the San Francisco River. The industry has only attained large proportions during the last forty or fifty years. The production amounted to about 100 million lb. in 1870, and was estimated in 1911 at about 150 million lb.; in 1912, 169 million lb.; and in 1913, 213 million lb. A large proportion of the crop is used in the cotton mills of the country. The cotton is generally detached from the seed by means of roller-gins. It is baled by crude hand-presses, and the cotton is therefore comparatively loosely packed, the bales weighing on the average only about 250 lb. each. The Brazilian cottons are known in commerce by the names of the ports from which they are shipped or by that of the province in which they are produced, as, for example, Maranham, Maceio, Paraiba, Ceara, and Pernam (an abbreviation for Pernambuco). Both herbaceous and arborescent forms are grown. The former are cultivated either as annuals or biennials whilst the latter continue to bear for eight years or more. The herbaceous cottons give a larger crop than the arborescent kinds but the latter produce a longer fibre.

In general, Brazilian cotton is white, harsh and wiry in character, of medium strength, from 1 inch to 1·4 inches long, and about 0·00080 inch in diameter.

During recent years, Sea Island, American Upland and Egyptian varieties have been introduced into Brazil, and have already become acclimatised.

. . . . .

Cotton is also cultivated to some extent in many other parts of South America, including Colombia and Venezuela. Attempts are being made to develop the industry in Argentina.

Production in Other Countries

Mexico.—Cotton was extensively grown in Mexico by the native Indians before the Spanish Conquest, and it is estimated that the annual production at that time amounted to about 116 million lb. Under the rule of the Spaniards the industry gradually declined until in certain parts of the country it was altogether abandoned. Since 1882, however, cotton growing has again received attention, and it is not improbable that Mexico will become an important contributor to the world's cotton supply. There are large areas well adapted to the plant in several of the States, but the principal region of production is the Laguna district in the States of Coahuila and Durango, where about 80 per cent. of the total crop is grown. The cultivation is carried on in this district under irrigation, controlled by works on the Nazas river. The fibre produced in this region is about 1·4 inches long, and of good strength, but is finer and less silky than American Upland cotton.

In many parts of the country, the cultivation is still conducted in a very primitive manner, but in the Laguna country and particularly on the Tlahualilo estate, owned by English and American capitalists, modern methods are employed. The cotton is liable to the attack of many pests, including the boll-weevil (*Anthonomus grandis*). The crop of 1908 is estimated to have amounted to about 70 million lb. and that of 1913 to about 75 million lb. During recent years, an immense manufacturing industry has sprung up, with the result that not only is the whole of the crop consumed locally, but a certain quantity of Texas cotton is imported.

Asiatic Russia.—Cotton is grown on an extensive scale in Turkestan and Transcaucasia.

Cotton growing is a very ancient industry in

Turkestan. It declined considerably immediately after the Russian occupation, but has now revived. The Russian Government have assisted the industry by laying out irrigation canals and establishing experiment stations. Efforts have been made to improve the staple by distributing American Upland seed to the growers together with instructions in the methods of cultivation printed in the local languages. In 1890, the crop amounted to 33,400,000 lb. of American cotton, and 12,900,000 lb. of the native Asiatic variety, whilst in 1909 it reached a total of 395,400,000 lb., consisting almost entirely of American varieties. The total production was about 400 million lb. in 1912, and 447 million lb. in 1913.

The rainfall is insufficient in the early period of the plant's growth, and irrigation is therefore necessary. The methods of cultivation are exceedingly primitive and but little attention is paid to manuring. Most of the cotton is ginned by a simple wooden machine resembling the "churka" gin of India, but modern ginning stations have been established at some of the larger centres. Labour is comparatively plentiful and cheap, and the rent of land is not high. The yield could doubtless be largely increased by the adoption of improved methods of cultivation, and the difficulties due to the climate could probably be overcome by breeding varieties adapted to the local conditions.

In Transcaucasia, an indigenous variety of cotton has been grown from very early times. This variety is still largely cultivated, whilst American Upland cotton is grown to a much smaller extent. The crop amounted to about 22 million lb. in 1891, and to about 28 million lb. in 1908, 56 million lb. in 1912, and 58 million lb. in 1913.

China.—The amount of cotton produced in China cannot be stated with any approach to accuracy, owing to lack of statistics, but is roughly estimated at 700 million lb. per annum. It is grown chiefly in the basin of the Yangtse River, the basin of the Hoang Ho or Yellow River, and the Province of Chekiang. The methods of cultivation are very primitive, and probably have not been varied for centuries. The farmer usually practises some form of rotation, and obtains two crops (such as wheat and cotton) or even three (such as wheat, cotton and beans) from the same land in one year.

Since 1895, several cotton-mills have been established in China in which the locally-grown cotton is chiefly employed. In spite of this, the exports of raw cotton have steadily increased, and during the years 1899—1908 amounted, on the average, to about 95,400,000 lb. per annum, about 90 per cent. of which went to Japan. In 1912 the exports were about 107 million lb., and in 1913 about 98 million lb.

Chinese cotton is of rough staple, about ½ to ¾ inch long; although shorter than Indian cotton, it is of whiter appearance and freer from seed and leaf. The fraudulent practice of watering the cotton to increase its weight before sale still continues, in spite of official proclamations forbidding it.

Japan.—The cotton plant is said to have been first introduced into Japan in 781 A.D. from India, but its cultivation soon ceased. It was probably re-introduced by the Portuguese in 1592.

About one-half of the crop is produced in West Japan, about two-fifths in Central Japan, and the remainder in Shikoku, Kiushiu, and North Japan.

There are three varieties of cotton plant in Japan, bearing white, yellow and red flowers respectively, of which the yellow kind predominates. The seed is sown at the beginning of May, and the crop is harvested in September. As soon as the first leaves appear, manures, such as oil-cake and fish-guano, are applied in the furrows between the plants. The plants are usually thinned out about the middle of June. Ginning is effected by a primitive implement known as the "rokuro" which corresponds with the Indian "churka."

The cotton is usually of good quality, of fair lustre and elasticity, but rarely more than three-quarters of an inch long. During recent years the production has gradually diminished, and the Japanese spinning industry has become more and more dependent on foreign supplies. In 1894 the production of unginned cotton was estimated at about 104 million lb., but in 1906 the output had fallen to about 13 million lb. The crop of ginned cotton for 1908 was estimated at about 3 million lb., and since that date the production has tended to undergo still further diminution.

The manufacturing trade has grown remarkably of late years, the amount of cotton consumed having increased from about 350 million lb. in 1900 to 455 million lb. in 1909. Of the 425 million lb. imported into Japan in 1908, about 200 million were secured from India, 106 million from the United States, and 87 million lb. from China.

Considerable attention is now being devoted to the cultivation of cotton in Corea. American Upland types have been introduced, and it is anticipated that before long the country will be able to supply a fair proportion of the raw material required by the Japanese mills. In 1913, the area planted with American cotton was 36,152 acres, and cotton to the value of nearly £50,000 was exported to Japan. In addition to this, it is estimated that over 100,000 acres were devoted to the native varieties.

Cotton Prices

The prices of the different kinds of cotton are governed more or less by that of a standard grade of American Upland cotton known as "middling" American (see page 53). The average value of this grade in Liverpool during the period 1899–1914 was about 6*d.* per lb., but the price is subject to violent fluctuations; in 1894, it fell below 3*d.* per lb., whilst in 1904, owing to the creation of a corner by American speculators, it rose to nearly 9*d.* per lb.

The comparative values of some of the principal kinds of cotton, when "middling" American is 7*d.* per lb., can be judged from the following prices which were quoted in the *Liverpool Cotton Association Weekly Circular* of the 6th March, 1914.

	Per lb.
American.	
American, middling	7*d.*
Sea Island, fine	13½*d.*
„ „ , fancy Florida	12¾*d.*
West Indian.	
Sea Island, fine	16½*d.*
„ „ , extra fine	19½*d.*
Egyptian.	
Brown Egyptian, fully good fair	8·90*d.*
Ashmouni „ „ „	8·30*d.*
Nubari „ „ „	9·15*d.*
Yannovitch „ „ „	10·05*d.*
Sakellaridis „ „ „	9·95*d.*
Abassi „ „ „	9·50*d.*
Indian.	
Machine-ginned Broach, good	5⅞*d.*
Oomra, No. 1, good	5½*d.*
Bengal, good	4⅝*d.*
Tinnevelly, good	6¼*d.*
Peruvian.	
Rough Peruvian, good fair	8·75*d.*
Smooth Peruvian, „ „	7·56*d.*
Brazilian.	
Brazilian, Pernam, good fair	7·64*d.*
„ Maceio „ „	7·59*d.*
„ Ceara „ „	7·59*d.*
„ Maranham „ „	7·59*d.*

A full discussion of the subject of cotton prices, together with statistical information, is given in *The World's Cotton Crops*, by John A. Todd (1915).

CHAPTER IV

COTTON GROWING IN BRITISH WEST AFRICA AND OTHER PARTS OF THE BRITISH EMPIRE

An account of cotton growing in Egypt and India has already been given. In the following pages, brief reference will be made to the position and prospects of the industry in other parts of the British Empire.

It has already been pointed out (page 51) that the Lancashire cotton industry is mainly dependent on the United States for its raw material. A diminution in the supply from this source is therefore liable to entail serious consequences. Such an occurrence was brought about by the American Civil War (1861–1864) when the price of cotton advanced to an extremely high figure and, as a result, thousands were thrown out of employment and much distress was produced throughout the country. During recent years, considerable inconvenience and anxiety have been occasioned in the cotton trade by a deficiency in the supply, aggravated by artificial fluctuations in price due to the manipulations of American speculators. The shortage is attributed to the fact that during the last thirty or forty years, the world's consumption of cotton has been increasing more rapidly than the supply. The greater part of this increase has taken place in the United States where the quantity of cotton used advanced from about 892 million lb. in 1880 to 2,830 million lb. in 1914 (cf. p. 51).

The danger to which the British cotton industry is exposed by its dependence on the United States led manufacturers to consider the possibility of obtaining supplies from other sources, and in 1901 a committee was appointed for the purpose of making the necessary enquiries. The committee reported that suitable cotton for the Lancashire trade could be grown in various parts of the British Empire. As an outcome of this report, the British Cotton Growing Association was inaugurated in June 1902 with the object of extending cotton growing in British Possessions. The Association immediately engaged in a series of experiments and enquiries in connection with which considerable help and encouragement was afforded by Government officials. The work of the Association together with that of the British and various Colonial Governments, as well as of private enterprise, has now resulted in the production of cotton on a commercial scale in several parts of the Empire, a brief account of which is given below.

Similar efforts have been made by Germany, France, Portugal and Belgium to encourage cotton cultivation in their various Colonies and Dependencies.

British West Africa

Cotton is found in the wild state all along the West Coast of Africa, and it has long been cultivated by the natives for their own requirements. The high prices ruling during the American Civil War proved a great incentive to the native growers and native buyers, especially in the Lagos Hinterland and parts of the Gold Coast. Great exertions were put forth by merchants, and ginning and baling machinery was introduced. At the close of the war, however, the price of cotton became normal again, and, in consequence, the industry rapidly declined.

During recent years, renewed efforts have been made to develop the cotton growing industry in the British, French and German Possessions in West Africa, and there is no doubt that there are vast areas which possess both soil and climate of a kind well adapted to the cultivation.

The exigencies of the climate are such that the actual cultivation can only be carried on by the natives, and the establishment of large European plantations is practically excluded. The endeavours of the British Cotton Growing Association, the (French) Association Cotonnière Coloniale and the (German) Kolonial-Wirtschaftliches Komitee have therefore been chiefly directed to encouraging the natives to increase the areas devoted to cotton and thus develop an export industry. These efforts have already met with considerable success, especially in the Southern Provinces of Nigeria, Dahomey, and Togoland.

Numerous attempts have been made to introduce exotic varieties, especially American kinds, into West African cultivation, but the indigenous plants appear to be the most hardy and to yield the most satisfactory crops. It would appear, therefore, that, in future, the most promising line of work will be to endeavour to improve the staple of the native varieties by the introduction of modern methods of cultivation and especially by a regular and sustained system of seed selection.

In the following paragraphs, a short account is given of the efforts which have been made in the different British West African Possessions and of the present position and prospects of the industry in each.

Nigeria: Southern Provinces.—It is probable that cotton has been a regular crop of the Southern Provinces for centuries; it is employed by the natives for the manufacture of their wearing apparel, and during the American Civil War large quantities were grown for export. The value of the exports in 1869 amounted to no less than £76,957, but from this time the quantity exported rapidly diminished until in 1879 the value of the exports was only £526. A small export trade has since been regularly maintained.

The British Cotton Growing Association have devoted more consideration to the Southern Provinces of Nigeria than to any other part of West Africa, and a great deal of excellent work has been accomplished in co-operation with the local Government. Experimental plantations were established at various centres for carrying out trials with different varieties, and for producing seed suitable for distribution to the natives. Buying stations and ginning factories were established, and the Association undertook to purchase seed-cotton from the natives at a minimum price of 1*d.* per lb. The results of the work on the experiment farms proved that such plantations under European supervision could not be commercially profitable. It was found that certain American varieties could be successfully established in the country, but it was not considered advisable to distribute large quantities of exotic seed which had not been thoroughly acclimatised. Efforts were therefore made to improve the native cotton by seed selection at the ginneries, and this was rendered possible by ensuring that all the buying centres came under the direct control of the Association and that the seed-cotton was ginned in their own factories. A regular system of seed selection has been conducted in this manner, with the result that the quality of the cotton has undergone a steady improvement. The undesirable varieties have been almost completely eliminated, and a product of regular grade is now being obtained which realises from 10 to 20 points (0·10*d.*–0·20*d.* per lb.) in advance of the current price of "middling" American cotton. This cotton is slightly over one inch in length, somewhat harsh and coarse, and of a brownish tint. Unfortunately the seed-cotton gives rather a small yield of fibre (27 per cent.) on ginning, but the cotton is very strong, and suffers but little waste in the manufacturing processes.

In order to deal with the large quantities of cotton seed which are not required for distribution, a mill was erected at Ibadan for the expression of cotton seed oil. It has been found, however, that in the absence of a local demand for the oil and cake it is more profitable to export the seed.

The best results have been obtained in the region formerly known as the Western or Lagos Province, where the natives have undertaken cotton growing with considerable zeal. This region is inhabited by the Yorubas, an industrious race, well versed in agricultural pursuits and fully able to grow the crop to advantage.

In the Eastern Province, much less cotton is produced as in the greater part of the country the rainfall is too heavy. It is noteworthy, however, that the best cotton grown in West Africa is produced in the Ishan District of this Province.

The cultivation of cotton in Nigeria cannot be carried on with success near the coast as the rainfall is too heavy, and the greater part of the crop is therefore produced in the interior, north of Ibadan. With a view to facilitating transport, the Lagos Railway was extended from Ibadan to Jebba in the Northern Provinces, and subsequently to Zungeru. This line was finally linked up at Minna with the railway which had been constructed from Baro to Kano. The increased transport facilities thus provided have enabled the industry to undergo great expansion.

The following are the quantities of cotton exported from the Southern Provinces of Nigeria during the years 1902–1916 :

Year.	Quantity (lb.).	Year.	Quantity (lb.).
1902	12,359	1909	5,032,916
1903	281,000 (approx.)	1910	2,478,316
		1911	2,238,190
1904	1,148,551	1912	4,372,773
1905	1,374,875	1913	6,361,120
1906	2,695,923	1914	5,649,840
1907	4,089,530	1915	2,697,072
1908	2,294,356	1916	7,454,160

These figures include the cotton passing through the country from the Northern Provinces.

Nigeria : Northern Provinces.—Cotton is grown extensively in parts of the Northern Provinces, and its cultivation is accompanied by a large manufacturing industry. The centre of this industry is at Kano, which for centuries has been renowned for its cotton goods, the trade in which is not limited to Nigeria or even to West Africa, but extends as far as the North of the Continent.

The native methods of cultivation show considerable variation. In some places, the cotton is grown as an annual crop ; in others, the plants are left in the ground for three years, whilst it is not uncommon for the plants to be allowed to remain until the crop becomes so small that it is hardly profitable to gather it and the plantations are then abandoned. In some localities, the cotton is grown in conjunction with yams.

There are enormous areas in the Northern Provinces suitable for cotton growing, and there are several indigenous cottons of good quality and well adapted for the English market. The cottons most widely grown are native varieties of *Gossypium peruvianum* which furnish fibre a little less than an inch in length.

The possibility of developing an export cotton industry was considered by the Niger Company in 1888, and samples of indigenous cottons were sent to England and were reported to be of rough but useful staple. Trials were made with American and Egyptian seed, and satisfactory results were obtained. The matter was not carried any further at that time, however, on account of difficulties of labour and transport.

The British Cotton Growing Association have established buying stations, erected ginneries, and carried out experimental work on the cultivation of American varieties of cotton. The experimental work is now being conducted by the Agricultural Department. In 1914 seed of the American variety, known as "Allen's Long Staple," which had been produced in 1913 on the Government plantation near Zaria, was distributed to the growers for cultivation under supervision. The plants produced from this seed gave a larger yield per acre than the native variety, and the seed-cotton was purchased by the British Cotton Growing Association at 1½*d.* instead of 1*d.* per lb.

The completion of the Baro-Kano Railway has opened up densely populated regions in the Zaria and Kano Provinces, and it is anticipated that a large and profitable industry will gradually be established. It must be remembered, however, that the amount of cotton available for export is limited by the demand for local manufacture, for which purpose higher prices are paid for the cotton than would be justified by the value of the product in Liverpool.

It is possible, moreover, that the extension of cotton growing may be restricted by the natives preferring to plant ground nuts, a crop which is well suited to the country and is rapidly increasing in popularity.

A large increase in the output of cotton has taken place recently, however, and during the first six months of 1916, the British Cotton Growing Association purchased over 10,000 bales of 400 lb. each.

There are no trustworthy figures available for the quantities of cotton exported from the Northern Provinces of Nigeria prior to 1908, but during the years 1908–12, the exports were as follows: 1908, 56,986 lb.; 1909, 140,080 lb.; 1910, 58,688 lb.; 1911, 92,373 lb.; 1912, 259,280 lb.; 1913–14, no separate returns for the Northern Provinces available.

Gold Coast.—In some parts of the Gold Coast, as in other regions of West Africa, cotton growing has long been practised by the natives, who employ the product for the manufacture of cloths for their own use. The cultivation is carried on in a very primitive manner. The cotton is not properly planted, but is usually grown in conjunction with various food crops, such as yams, maize, and cassava. As a rule, the plants are not cut down at the end of each season and, in some cases, they are allowed to remain in the ground for many years. Cotton is picked from the plants as long as it is worth gathering, but the fibre rapidly deteriorates and after the first year is generally of very poor quality.

Some of the indigenous varieties are of very fair quality, and if carefully cultivated could probably be considerably improved. Several attempts have been made to introduce exotic cottons. An acre of land at Aburi was planted with Egyptian cotton in 1890 and gave a satisfactory yield. During the same year an experiment with Egyptian cotton was carried out at Accra and a crop of good quality was produced. From this time onward the native farmers were encouraged by the Agricultural Department to devote attention to cotton cultivation, and large quantities of American and Egyptian seed were distributed. These efforts, however, did not meet with much success.

In 1903, the British Cotton Growing Association commenced work in the Gold Coast, and a cotton expert was appointed who was attached to the Agricultural Department. A tour was made of the country with the object of ascertaining the suitability of the various districts for the crop. Large quantities of American Upland seed were distributed and the natives were urged to extend the cultivation. In certain selected districts small experimental plantations were established under the supervision of the native chiefs. In 1904 an experiment farm was started at Labolabo near the Volta River, and 120 acres were planted. In the following year several varieties, including native, American and Egyptian kinds, were grown at this farm. The American cottons gave the largest yields, and the Egyptian the smallest yields. The experiments were continued in 1906, and as a result the conclusion was reached that the climate was not suited to the growth of Egyptian varieties. The best results with exotic cottons were obtained with the American variety known as "Black Rattler." A steam ginnery and buying station were established at Labolabo. The natives, however, did not make much progress in the industry, although some advance took place in the Peki District. In 1910, the British Cotton Growing Association discontinued the agricultural work, and this was subsequently resumed by the Agricultural Department. The Association, however, still continued to take an active part in the commercial side of the industry.

The exports of cotton from the Gold Coast during 1903–1916 were as follows:

Year.	Quantity (lb.).	Year.	Quantity (lb.).
1903	10,443	1910	11,421
1904	57,661	1911	9,701
1905	29,124	1912	20,395
1906	92,886	1913	27,497
1907	56,088	1914	23,514
1908	51,480	1915	12,016
1909	31,290	1916	17,896

It is evident from these figures that the vigorous efforts which have been made to foster the industry have not yielded encouraging results. The disinclination of the natives to grow cotton was formerly due to the fact that they could provide for all their requirements by means of palm-oil and palm-kernels, the preparation and collection of which entail comparatively little labour. Moreover, it happened, very unfortunately from the point of view of the cotton industry, that just at the time when the British Cotton Growing Association were striving to stimulate cotton growing, cocoa cultivation came into prominence. This crop is more profitable to the native than cotton, and large numbers are now engaged in its production. The exports of cocoa increased from about 5 million lb. in 1903 to more than 118 million lb. in 1914.

In spite of the lack of success attending the earlier efforts, the Agricultural Department of the Gold Coast continued their endeavour to create a large cotton industry in the country. The sphere of work was transferred to the Northern Territories, and an agricultural station was established at Tamale in 1909, where experiments were made with the object of ascertaining the best variety to grow, the most satisfactory time for planting, and the most suitable crops to grow in rotation with cotton. Attempts were also made to acclimatise exotic varieties, and to produce improved strains of indigenous cottons by selection and hybridisation. Unfortunately, however, these attempts to develop cotton growing in the Northern Territories did not meet with success. The yield of cotton was exceedingly small, and it was considered useless to continue the efforts. In 1915 the enterprise was therefore abandoned.

Sierra Leone.—Cotton is indigenous to the country, grows in almost all parts of the Protectorate, and is cultivated by the natives for the manufacture of a coarse kind of cloth which they wear much more commonly than imported cotton goods.

The methods of cultivation employed by the natives are of a very primitive description. After cutting or burning the bush, the field is roughly hoed. At the commencement of the rainy season, cassava is planted, and a mixture of cotton seed with that of various food crops, such as sesame, "okra" (*Hibiscus esculentus*), and rice, is sown broadcast. The cotton plants are usually allowed to remain in the ground for two or three years and sometimes attain a height of 10 feet.

Attention was drawn to Sierra Leone as a promising country for cotton growing in 1890, when a supply of Egyptian seed was forwarded for experimental trial. The results of this experiment however do not appear to have been successful.

In 1902, the British Cotton Growing Association commenced operations in Sierra Leone by sending out an American cotton expert to carry out experiments with the object of improving the quality of the cotton grown, and also to endeavour to persuade the natives to grow cotton for export. An offer was made of 1*d*. per lb. for all the seed-cotton brought in for sale. American and Egyptian seed was distributed among the chiefs in the Protectorate, but the results were unsatisfactory. The Government attempted to encourage the industry by carrying machinery or implements for the cotton plantations and consignments of cotton for export free of charge on the Government Railway.

In 1904, the British Cotton Growing Association leased from one of the chiefs a large area of land, adjacent to the Railway at Moyamba in the Ronietta district of the Protectorate, and established an experimental plantation. The crop for that year was very disappointing owing to unfavourable weather, the rainfall amounting to more than 100 inches. The quantity of cotton exported amounted to about 13 tons.

In 1905, an area of 1,030 acres was cultivated at Moyamba, a large part of which was devoted to experiments with seed of imported varieties in order to discover the kind best adapted to the country. The most favourable results however were obtained with the native "Quondi" variety which furnishes cotton of a pale cream colour and about 1 inch long. A ginning station was erected, but owing to a recurrence of unfavourable conditions, the exports during the year only amounted to about 31 tons.

The results obtained in 1906 were again disappointing, and in spite of the efforts of the British Cotton Growing Association, the cotton exported amounted to only 39 tons, and was of poor quality. It was therefore decided to discontinue the work, and the Moyamba plantation was abandoned.

The outcome of these efforts to create a cotton growing industry in Sierra Leone has been to show that the native "Quondi" cotton can be grown satisfactorily, but that the rainfall is too heavy for the cultivation of exotic varieties. The natives are not attracted to cotton growing in the forest areas where oil-palm, rubber and piassava trees abound, but it is possible that beyond these regions they would take to the industry if transport facilities were provided. The natives are, however, naturally indolent, and are not easily persuaded to exert themselves to produce anything that is not required for their own immediate needs.

Although the British Cotton Growing Association have withdrawn from Sierra Leone, experimental work on cotton cultivation has not been altogether abandoned but is being continued by the Department of Agriculture.

The quantities of cotton exported from Sierra Leone during the years 1903–1915 were as follows:

Year.	Quantity. lb.	Year.	Quantity. lb.
1903	1,120	1907	13,006
1904	28,267	1908	336
1905	68,808	1909–15	nil
1906	87,805		

Gambia.—The cultivation of an indigenous variety of cotton has long been carried on by the natives of the Gambia in a very primitive manner. The crop is used for the manufacture of the "pagns" or native cloths which are in considerable demand locally. Small quantities of the cotton have occasionally been exported; in 1843 the exports amounted to about 31 tons. An effort was made to stimulate the industry in 1862 when a ton of Egyptian cotton seed was forwarded to the Colony and distributed to growers. This trial resulted in 47 tons of cotton being purchased from the natives.

In 1890 a further quantity of Egyptian cotton seed was forwarded to the Colony. The plants raised from this seed appear to have given good results.

In 1902 the British Cotton Growing Association directed their attention to the Gambia, and an American cotton planter was engaged to make a tour of the country and report on the prospects of the cultivation. Supplies of American and Egyptian seed were forwarded to the Colony and distributed to the natives. A little later, an Experiment Farm was started at Willinghara in the Upper River District, and a study was commenced of the climatic conditions in their relation to the growth of cotton, and seed selection experiments were undertaken with both native and imported varieties.

During 1902, the Government purchased the seed-cotton grown from imported seed at 1½*d.* per lb., but the natives were dissatisfied with the price, as there was a local market for the product at 2*d.*–3*d.* per lb. for making the "pagns" already mentioned. In the following year, therefore, the Government purchased the crop at 2*d.* per lb., but the payment of so high a price for seed-cotton resulted in a considerable loss. In 1905, the natives were offered only 1*d.* per lb. for seed-cotton, and since they refused to sell at that price the enterprise was abandoned.

The amount of cotton exported from the Gambia during 1901–1915 was as follows:

Year.	Quantity (lb.).	Year.	Quantity (lb.).
1901	48	1906	129
1902	120	1907–13	nil
1903	1,560	1914	126
1904	59,828	1915	nil
1905	2,572		

The results of this endeavour have clearly demonstrated that the natives of the Gambia will not take up cotton growing for export. Ground-nut cultivation, which is the chief industry of the Colony, is more profitable than cotton growing, and gives a sufficient return to supply all the needs of the people. Moreover, the country is only sparsely populated, and the climatic conditions do not appear very favourable to cotton growing on a large scale.

Anglo-Egyptian Sudan

Cotton growing has made rapid progress in the Sudan during recent years. The rainfall is insufficient for the crop in the north of the country, and irrigation is therefore practised. In the south, however, a certain amount of cotton is grown which depends entirely on the rainfall. The following are the principal districts in which the crop is produced.

About sixty miles south of Suakin in the Red Sea Province, the Baraka River forms a large delta, in the centre of which is the village of Tokar. The rainfall in this region is inadequate for cotton growing, and the only area available for cultivation is that which is watered by the annual overflow of the Baraka River. Unfortunately the flood varies greatly in amount from year to year, and, moreover, a large quantity of the water runs to waste as at present there is no means of controlling it. A scheme has been drawn up with a view to preventing this loss of water but has not yet been put into operation. The industry is somewhat hampered by the difficulty of transport, but this would be solved by the provision of a railway from Tokar to Suakin or Port Sudan. The cotton at present grown at Tokar is almost entirely of the Egyptian Mitafifi variety, but experiments which have been continued for several years indicate that long-stapled American cottons may eventually be found more profitable.

In the Khartoum district, and in the Nile Valley north of Khartoum, are a number of areas cultivated by pump irrigation. The largest of these areas is that of the Sudan Plantation Syndicate at Zeidab in the Berber Province, where in some years successful results have been obtained with both Egyptian and American varieties.

South of Khartoum and between the Blue and White Niles is an extensive plain, known as the Gezira, which has an area of about 4 million acres. The soil of this region is well adapted for cotton growing, but, owing to the low rainfall, irrigation is necessary. An elaborate scheme has been devised for effecting the irrigation of the Gezira and, as a preliminary step, an experiment farm has been established at Tayiba with a pumping installation to supply the necessary water. The success obtained at this farm has demonstrated the possibilities of cotton growing in the region. The construction of a main irrigation canal has been commenced, which is to leave the Blue Nile at Sennar and run northwards parallel to the course of the river. A pumping station has also been erected at Barakat, a little south of Wad Medani, and a large area was planted with cotton in 1914.

In Kassala, a considerable quantity of Mitafifi cotton is grown under conditions similar to those prevailing at Tokar, the land being watered by the flood of the River Gash.

Estimates of the quantities of seed-cotton produced in the different districts of the Sudan in 1912–13 and 1913–14 are given in the following table.

	1912–13. Metric tons.	1913–14. Metric tons.
Tokar (flood grown) . . .	5,140	2,983
Khartoum and Nile Valley North of Khartoum (pump irrigation)	1,209	1,523
Tayiba (Gezira) (pump irrigation)	507	336
Kassala (flood grown) .	248	322
Gallabat (rain grown) . .	124	42

The total exports of cotton (calculated as ginned cotton) from the Sudan during 1901–1916 were approximately as follows :

Year.	Quantity (lb.).	Year.	Quantity (lb.).
1901	881,600	1909	2,865,200
1902	110,200	1910	6,391,600
1903	808,100	1911	9,129,200
1904	1,322,400	1912	6,000,000
1905	1,469,300	1913	5,132,000
1906	1,689,700	1914	3,774,000
1907	3,232,500	1915	9,492,000
1908	3,967,200	1916	6,488,000

The fluctuation in the quantity produced from year to year is largely due to variations in the Tokar flood conditions.

Uganda Protectorate

The cultivation of cotton in Uganda on a commercial scale was first undertaken in 1904, when seed of several different varieties was introduced by the Government and the Uganda Company. It was found that American Upland cottons were superior to Egyptian varieties, as they gave larger yields per acre, were hardier, matured more rapidly, and proved better adapted to the local conditions. Unfortunately owing to the lack of any organisation for controlling the industry, the seed became mixed, and for some years the crop consisted of a mixture of the different varieties which had been introduced in which the American Upland character largely predominated. The staple was consequently very irregular, and spinners expressed dissatisfaction with the product. In 1908, the Government turned their attention to the matter, and an Ordinance was enacted under which rules were made which prohibited the sowing of any seed except that provided by the Government. An American Upland variety, known as "Black Rattler," was distributed to the growers, and efforts were made to eradicate all cotton of the Egyptian type. A more uniform type of cotton was thus produced, but the quality was still of a somewhat low grade. The Agricultural Department, therefore, endeavoured to effect the production of an acclimatised cotton of superior quality, and work in this direction has been continued for several years. A seed farm has been established, and pure American long-stapled varieties have been substituted for the various hybridised forms previously grown. In the year 1913–14 the whole of the main crop was of "Allen's Long Staple" variety.

Transport difficulties offer a serious hindrance to the extension of the industry. The seed-cotton, in loads of about 60 lb., is carried on the heads of the natives, sometimes for very great distances, to the nearest buying station. After being ginned, the cotton has to be conveyed to the railway connecting Lake Kioga with Jinja on the Victoria Nyanza, whence it is shipped across the lake to the terminus of the Uganda Railway.

In spite of these obstacles, however, the Uganda cotton industry has developed with great rapidity, as is shown by the following table, giving the quantities and value of the exports during the years 1904–1915.

Year.	Quantity. lb.	Value. £
1904	21,566*	235
1905	96,098*	1,089
1906	391,244*	11,411
1907	1,605,184†	51,594
1908	1,625,755†	41,232
1909	2,595,152†	59,596
1910	5,538,885†	165,412
1911	8,343,813†	230,850
1912	10,517,621†	254,379
1913	11,191,824†	317,687
1914	13,126,587†	351,146
1915	10,520,610†	245,426

* Partly ginned and partly unginned, the quantity of each kind not being separately stated.

† Ginned cotton (export of seed-cotton having been converted on the assumption that 1 lb. of ginned cotton is obtained from 3 lb. of unginned).

East Africa Protectorate

From 1904 onwards, efforts have been made by the Department of Agriculture and the British Cotton

Growing Association to promote cotton cultivation in the East Africa Protectorate. European planters have grown cotton, chiefly of Egyptian varieties, in a few districts, especially near the coast in the neighbourhood of Malindi, and in the Tana River Valley. Unfortunately this enterprise has not proved very successful, and in most places the natives are not inclined to take up the industry as they prefer the cultivation of food-crops. It has been proved that cotton growing near the coast is not profitable, except on the banks of the Tana and Juba Rivers where irrigation can be effected. In the Lake District of the Nyanza Province, however, the conditions are favourable, and the natives are now planting cotton as an adjunct to the cultivation of sesame and other food-crops; it is anticipated that the production in this district will gradually increase.

The exports of cotton from the East Africa Protectorate during the years 1904–1914 are shown in the following table.

Year.	Quantity. lb.	Value. £
1904	28,880	285
1905	99,456	1,273
1906	102,256	1,407
1907	81,100	1,843
1908	251,328	5,907
1909	141,792	4,440
1910	163,184	7,477
1911	166,033	6,313
1912	295,232	11,831
1913	134,875	5,476
1914	17,465	614

Reference may be made to the cultivation of cotton in German East Africa, where much greater success has been obtained than in the British Protectorate. It has been found that American Upland varieties are best adapted for native cultivation. The crop cannot be grown very satisfactorily near the coast, but several districts in the interior possess favourable

PLATE IV

From the Collections of the Imperial Institute

COTTON FIELD, NYASALAND PROTECTORATE

From the Collections of the Imperial Institute

BALING COTTON, NYASALAND PROTECTORATE

conditions for the industry. The exports have rapidly increased and in 1912 they amounted to 4,139,513 lb. of value £105,512, and in 1913 to 4,828,964 lb. of value £120,753.

Nyasaland Protectorate

Cotton growing was introduced into Nyasaland in 1903. Unfortunately, just as in the case of Uganda, a large number of different varieties were planted with the result that considerable confusion occurred, owing to hybridisation and the mixing of the seed. Subsequently all the varieties were discarded with the exception of Egyptian kinds, which are now confined to the warmer districts of the Lower River, and long-stapled American Upland forms, which are cultivated on the higher lands. As a rule, Egyptian cottons are grown in Nyasaland at elevations below 2,000 feet, and American Upland kinds from 2,000 to 4,000 feet. Considerable attention has been given to the industry by the Agricultural Department, and an excellent long-stapled American Upland form has been acclimatised, which is known as "Nyasaland Upland" and is valued in Liverpool at about *2d.* per lb. in advance of "middling" American. The area devoted to the crop by European planters during the season 1913–14 amounted to 25,697 acres, of which 160 acres were planted with Egyptian cotton and the remainder with the Nyasaland Upland variety. A large and gradually increasing quantity of cotton is also grown by the natives.

The development of the industry is hindered by the lack of transport facilities. The only railway at present in existence runs from Blantyre to Port Herald on the Shire River, where the cotton has to be conveyed on barges to the Zambesi River, and thence down the latter river to Chinde on the coast of Portuguese East Africa. At Chinde the cotton has to be transferred to other barges which carry it to Beira, whence it is shipped to Liverpool. A railway from Port Herald to the Zambesi is now nearly completed, and negotiations are in progress for the construction of another line from the Zambesi to Beira. When these railways are open for traffic, the industry will probably make rapid progress.

The growth of the Nyasaland cotton growing industry is shown by the following figures giving the quantities and values of the exports from 1902 to 1916.

Year.	Quantity. lb.	Value. £
1902	692	No complete returns
1903	56,897	1,778
1904	285,185	5,941
1905	776,640	16,180
1906	526,119	15,345
1907	403,486	13,998
1908	756,120	28,355
1909	858,926	26,209
1910	1,736,999	58,687
1911	1,359,904	44,199
1912	3,237,555	80,939
1913	2,401,142	65,486
1914	2,648,508	72,068
1915	3,065,248	68,586
1916	3,462,400	127,131

British West Indies

Cotton was cultivated on an extensive scale in the West Indies in the eighteenth century, and during the years 1786–1790 no less than 70 per cent. of the world's commercial supply was obtained from these islands. Recent efforts to resuscitate the industry have met with great success. Sea Island cotton is the chief variety grown, but a small quantity of a native type, known as "Marie Galante," is also produced, especially in the island of Carriacou, the chief dependency of Grenada; the latter cotton has a length of about 1·2—1·4 inches. Sea Island cotton is usually considered to be indigenous to the West Indies, but the present crops are not obtained from the native plant, but are chiefly derived from seed of the "Rivers" type, which was imported from the Sea Islands of South Carolina in 1903 by the Imperial Department

Photograph by W. N Sands, F.L.S.

GINNING FLOOR, CENTRAL COTTON GINNERY, ST. VINCENT

Photograph by W. N. Sands, F.L.S.

SHIPPING BALES OF SEA ISLAND COTTON, ST. VINCENT

of Agriculture. The product is mostly of a very fine grade and realises excellent prices. The largest quantities are produced in the Leeward Islands, St. Vincent, and Barbados. The most valuable is grown in St. Vincent where, during the last few years, some of the finest crops have realised from 2*s.* to 2*s.* 9*d.* per lb. Cotton of very high grade is also produced in St. Kitts. The bulk of the West Indian cotton is from 1¾ to 2 inches long, and usually obtains prices ranging from 1*s.* 3*d.* to 1*s.* 11*d.* per lb.

Ever since the re-introduction of Sea Island cotton into the West Indies, continuous selection experiments have been carried on with the object of maintaining the quality of the crop and of establishing improved strains particularly adapted to certain districts. The plants are very subject to the attack of insect and fungoid pests, and these have therefore been made the subject of careful study with a view to their control. Remedial measures have been devised, and in order to avoid the transference of pests from one island to another the cotton seed is disinfected before sowing.

The following are the approximate quantities of cotton exported from the West Indies in 1903–1914.

Year.	Quantity. lb.	Value. £
1903 . . .	414,000	7,831
1904 . . .	776,000	28,029
1905 . . .	1,199,000	54,251
1906 . . .	1,662,000	83,705
1907 . . .	2,625,000	198,118
1908 . . .	2,762,000	175,093
1909 . . .	2,225,000	110,992
1910 . . .	2,138,000	135,222
1911 . . .	3,068,000	197,367
1912 . . .	2,388,000	143,065
1913 . . .	2,637,000	154,397
1914 . . .	2,304,400	131,525

The quantities and values of the cotton exported from the different parts of the British West Indies in 1913 were as follows :

	Quantity. lb.	Value. £
Bahamas	13,466	221
Jamaica	69,296	4,128
St. Lucia . . .	4,000	200
St. Vincent . . .	484,975	36,191
Barbados. . . .	433,099	23,460
Grenada	400,793	10,500
Leeward Islands . .	1,224,172	79,169
Trinidad and Tobago .	7,046	528
Total . . .	2,636,847	154,397

Cyprus

Cotton was grown extensively in Cyprus in the middle ages, and considerable quantities were exported to England in the seventeenth and eighteenth centuries. A large export trade was developed during the American Civil War, but since that time the industry has declined. The cotton grown is chiefly of a native type, and yields short, coarse fibre. American Upland cotton is also cultivated, but, owing to the rainfall being deficient and irregular, it is necessary that irrigation should be practised if crops of good quality are to be produced. A large part of the cotton is used locally, and the remainder is exported, chiefly to Marseilles and Trieste. The production has increased greatly during the last few years, that of 1904 amounting to 534,254 lb. whilst that of 1913 was no less than 4,614,999 lb. The exports in the years 1910–1915 were as follows:

Year.	Quantity. lb.	Value. £
1910 . . .	806,736	24,538
1911 . . .	785,904	22,593
1912 . . .	1,546,496	40,085
1913 . . .	1,505,728	40,693
1914 . . .	1,048,992	27,605
1915 . . .	700,112	16,306

. . . . .

Cotton is being grown to a small extent in Malta, Rhodesia, the Union of South Africa, Ceylon, Queensland, Fiji, and Papua. Detailed accounts of the industry in all parts of the British Empire in which the crop is cultivated, are given in "*Papers and Reports on Cotton Cultivation, presented to the International Congress of Tropical Agriculture, Brussels, May, 1910,*" and a summary of this information is contained in the "*Report on the Present Position of Cotton Cultivation,*" by Professor Wyndham R. Dunstan, C.M.G., LL.D., F.R.S., which was presented to the same congress.

Reports on the quality and value of a large number of British-grown cottons have been published in the pages of the "*Bulletin of the Imperial Institute,*" and in Professor Dunstan's "*British Cotton Cultivation*" (Cd. 3,997, 1908).

The areas under cotton cultivation and the amounts produced in the various parts of the Empire, together with the quantities and values of the cotton exported therefrom, are recorded annually in the official *Statistical Abstract for the Several British Self-governing Dominions, Crown Colonies, Possessions, and Protectorates.*

CHAPTER V

FLAX, HEMP, AND RAMIE

FLAX

Flax is a fibre obtained from the stems of *Linum usitatissimum*, of the natural order Linaceæ, which is cultivated over wide areas in the temperate and sub-tropical regions of both hemispheres. The plant is grown not only for fibre, but also for its seed which is known in commerce as linseed. In European countries, it is grown chiefly for fibre, except in Russia where large quantities of both seed and fibre are produced. As a general rule, the flax plant is grown either for fibre only or for seed only, for although a certain amount of linseed can be obtained as a by-product of flax cultivation, attempts to obtain both products from the same crop usually result in the production of an inferior quality of each.

The flax plant is an annual with a slender, erect stem, branching only at the top and bearing blue flowers; the fruit is a small five-celled capsule containing ten seeds.

Climate and Soil

The flax plant flourishes best in the colder parts of the temperate zone, which are not liable either to excessive heat or to drought. During the period of growth, the climatic conditions should be fairly equable, so that the plants may not receive any check to their regular development. Coast lands, in which the sky is often clouded and the atmosphere is humid, are particularly favourable.

The most suitable soil for the flax crop is a moist, well-drained, loamy or somewhat sandy soil, containing a large proportion of organic matter. The sub-soil should be rather compact and heavy and retentive of moisture.

Cultivation

Land selected for flax growing should be level, as an undulating surface by exposing some of the plants and shading others tends to produce uneven stems, and fibre of irregular quality. The preparation of the land varies with the locality, the nature of the soil, and the preceding crop. Lands on which a cereal crop has been grown, and which are of a compact nature are usually ploughed to a depth of from 6 to 8 inches in the autumn, and are harrowed and rolled in the following spring to produce a satisfactory seed-bed. In the case of light soils, deep ploughing is sometimes injurious, and surface tillage for the destruction of weeds is sufficient, the sub-soil thus being left undisturbed.

If the soil is poor, manurial treatment is necessary. Direct manuring with farmyard manure is not recommended, as it leads to the production of an uneven crop and coarse stems. This manure, however, may be applied indirectly with advantage, some other crop being grown on the manured land before the flax is planted. The refuse from the retting and scutching processes and any flax stems not used for fibre should be returned to the soil. Artificial manures may be applied in accordance with the requirements of the particular soils. Potash manures, especially in the form of kainit, or chloride or sulphate of potash, have been found to give good results, and it has been observed that they also check the "yellowing" of the flax crop, which is due to the fungus, *Asterocystis radicis*.

A flax crop should not be grown repeatedly on the same land, but a rotation system should be adopted. Suitable crops for such rotations are maize, oats, clover, wheat, potatoes, and legumes. Only seed of the highest quality should be used for sowing; either Riga (Russian) or Dutch seed is generally employed.

The seed should not be sown until all danger from frost is past, since frost has the effect of causing the young plants to branch and thus become of little value for fibre production. The seed is sown broadcast and is sometimes mixed with dry earth to facilitate its even distribution. After sowing, the land is lightly harrowed and rolled. The amount of seed sown per acre should be sufficient to ensure the production of plants so close to one another as to yield tall, slender, unbranched stems. The usual quantity is about 3 bushels per acre, but sometimes as much as 5 bushels is used. The ground must be kept well weeded.

Harvesting is effected when the lower portions of the stems begin to turn yellow, the leaves commence to fall and the uppermost capsules become pale brown. The crop is usually pulled by hand, the stems being grasped just below the capsules and jerked upwards; any bending or twisting of the stems should be avoided. The stalks should be sorted to some extent as they are pulled, and any coarse or branched stems should be put aside to be used for tying the stems into small bundles. The bundles of stems are stood on end in shocks to dry. In countries where labour is scarce, the stems are cut with a reaping machine, but this method is open to the objection that the fibre is shorter and is said to be inferior in spinning quality to that from the hand-pulled stalks. Moreover, sorting is impracticable in this case, and the fibre is therefore of irregular quality. It is also stated that the stems do not keep so well when stacked as the cut ends admit moisture.

The yield of fibre is usually about 4—5 cwts. per acre, but larger crops are sometimes obtained.

Diseases and Pests

The principal pests by which the flax plant is attacked are the flax yellowing and flax-wilt fungi, flax-rust, and the flax dodder.

"Flax yellowing" is the most formidable disease to which the crop is subject. It is caused by the fungus, *Asterocystis radicis*, which attacks the young plant when about 3 or 4 inches above the ground. The stem of the plant becomes yellow, the lower leaves wither and fall, and eventually the plant looks as if it had been burned. At the first signs of the disease, all affected plants should be pulled up and destroyed. If a whole field should become infected, flax should not be grown in it again for at least 8 or 10 years.

The flax-wilt disease is due to *Fusarium lini*, and is first recognised by the withering of the young plants. It usually appears in patches of a few feet in diameter and, if unchecked, it gradually spreads throughout the whole crop. The disease is transmitted from place to place by means of spores attached to the flax seeds. If the seeds intended for sowing are sprayed with a solution, containing 1 pint of commercial formalin in 40 gallons of water, any spores present on the seeds are killed, This treatment must be applied in such a way as merely to moisten the seeds, since if they are actually wetted they tend to stick together. The fungus is liable to persist in the soil and infect successive crops; such land is said to be "flax-sick." It is therefore inadvisable to grow two crops of flax in succession on the same land, but a rotation of crops should be adopted.

Flax-rust is due to another fungus, *Melampsora lini*. The disease can be detected by the presence of small orange spots on the stems, leaves or sepals, or by the occurrence of smooth, black patches on the stem. Affected plants should be uprooted and burned.

The flax dodder (*Cuscuta epilinum*) is a parasitic plant of the natural order Campanulaceæ, and its seeds are often found mixed with those of flax. The dodder attaches itself to the stem of the young flax plant and draws its nourishment from it, with the result that the growth of the flax plant is checked and the stems are rendered of no value for fibre. The dodder seeds are much smaller than those of the flax plant, and can be removed from the latter by means of a sieve of fourteen meshes to the linear inch.

Plants attacked by dodder should be pulled up and burned.

Preparation of Flax Fibre

Flax fibre consists of the bast tissues of the stem, and is situated immediately beneath the epidermis and surrounds the woody core. The fibrous filaments are naturally united to one another by gummy substances, known as pectoses, and in order to effect the isolation of the fibre in a suitable condition for the manufacturer, these substances must be removed.

Rippling.—The first step in the treatment of the flax stalks or "straw" is the removal of the seed capsules, which is effected by the process of "rippling" or "seeding." A handful of the straw held in such a manner that the upper ends are spread out, is pulled through the teeth of the rippling-comb which consists of a vertical row of round steel teeth, firmly fixed in a block of wood. In the best rippling-combs the teeth are about 18 inches long, $\frac{3}{16}$ inch apart at the bottom and $\frac{1}{2}$ inch at the top, the tapering being confined to the last three inches. The process is sometimes carried out by means of the seeding-machine, which consists of two heavy cast-iron rollers, revolving within a cast-iron frame; the lower cylinder is driven from pulleys, whilst the upper one turns in contact with the lower, and releases the seed by the pressure of its weight on the capsules. More complicated machinery is sometimes employed.

In the case of the Courtrai flax, the stalks are not rippled directly they have been pulled, but are dried and stacked until the following season.

After the straw has been rippled, it is tied up in small, loose bundles, and is then ready to be submitted to the retting process.

Retting.—This is the most important process in the preparation of the fibre. It consists essentially in submitting the straw to the action of water and allowing fermentation to take place. This effects the conversion of the insoluble "gummy" matter into soluble substances which are removed by the water.

The fermentation is due to the agency of bacterial organisms, which convert the pectose into soluble products but do not attack the cellulose or true fibre substance. This change is said to be brought about by the activity of a special enzyme, pectosinase, which converts pectose successively into pectin and sugar, the bacteria afterwards fermenting the sugar with the production of hydrogen, carbon dioxide, and a little butyric acid. There are several different methods employed for carrying out the retting process.

In many parts of Russia, especially the Archangel district, "dew-retting" is practised. The freshly-pulled straw is spread out in rows on the grass in a moist meadow, about a ton to the acre, and is left exposed for two or three weeks or more to the action of the air, light, dew and rain. From time to time the straw is turned over with a fork or a pole in order to ensure that it may all become equally retted. Dew-retting is the least satisfactory method, as the product is liable to be uneven.

The method of retting most commonly adopted is that of "water-retting" or "steeping." This process may be carried out either in pools or in running water. In the former case, the bundles of flax straw are placed side by side in a pool or dam with the root-ends downwards; when one layer is finished a second layer is placed on top of it in the same way, and so on until the dam is full. The whole is then covered with stones or with boards on which grass sods, stones or clods of earth are piled in order to keep the flax submerged. As fermentation proceeds, the gases which are evolved tend to raise the flax above the surface of the water, and at this point therefore it must be more heavily weighted. On the other hand, as the fermentation subsides the flax begins to sink, and some of the load must be removed. The straw must be examined from time to time in order to ascertain whether the retting has proceeded far enough. The determination of the exact point at which to stop the process requires considerable experience and judgment. In general, it may be said that when the fibre can be readily and completely separated from the woody core, it is time to withdraw the stems from the pools. After their removal from the pool, the bundles of straw are stood on end to dry and are then stacked for a few weeks. In some places, the bundles are drained and then "grassed," *i.e.* spread evenly over a grassy meadow to dry.

The water used for retting should be as soft as possible, and should not contain much iron or other substances likely to discolour the fibre.

In some parts of Russia, a combination of dew-retting and pool-retting is practised, the straw being first immersed for some time in shallow pools, and afterwards spread out on the grass and exposed to the action of the dew.

The process of retting in running water is carried out in the Courtrai district of Belgium, and yields flax of the finest commercial grades. The bundles of flax straw are packed root-end downwards in wooden crates, which are about 12 feet square and have a solid floor but open sides. A strip of jute sacking is bound round the sides, and the crate is placed in the river Lys, and loaded with stones until the water just covers it. From four to fifteen days are required for the necessary amount of fermentation to take place, the actual time depending on the temperature, the condition of the straw and other factors. When the retting is completed, the crates are withdrawn from the stream, and the bundles of straw are removed and dried in the air. In some cases the straw is again packed in the crates and immersed for a second time.

Many attempts have been made to improve the retting process by carrying it out in tanks or vats containing warm water. The first invention of this kind was made in 1846 by R. B. Schenk, who designed large wooden vats in which the flax straw was packed with the root-ends downwards. Water was introduced into the vats and maintained at a temperature of 75°–95° F. Fermentation rapidly ensues under these conditions, and the entire process only occupies about fifty or sixty hours. An improvement was suggested by Pownall, which consists in passing the straw, immediately after its removal from the vats, between heavy rollers over which a continuous stream of water is made to flow. This operation frees the straw from the slimy matter adhering to it, and also facilitates the subsequent breaking and scutching operations.

A further development of this method is embodied in the Legrand process, which was patented in the United Kingdom in 1904. The straw is packed, root-end downwards, in wooden crates similar to those used in the Courtrai district. A series of three tanks is employed, in which the water is maintained at 86°–88° F. These tanks are termed the "scouring" tank (A), the "retting" tank (B) and the "rinsing" tank (C). The crates are lowered into tank A by means of an overhead travelling crane, and allowed to remain there for twenty-four hours. During this time, however, they are occasionally raised by means of the crane, and held over the tank for a few minutes to allow the water to drip through the bundles, and then again plunged into the water, so that the latter rises right through the straw and ensures that the steeping is even throughout. The crates are then transferred to tank B, and allowed to remain, with occasional lifting and re-lowering, until the retting is completed; this takes from 2½ days, in the case of poor straw, to 3½—4 days with good, heavy straw. Finally the crates are placed in tank C, in which the straw is rinsed and the adhering impurities washed away. The process requires to be carefully watched in order that the flax may be withdrawn from the retting tank at the right moment. The clean, warm water is admitted in a slow and continuous stream at the bottom of tank C, and is siphoned over successively into tanks B and A. After the crates have been taken from the rinsing tanks they are placed on trucks and left for a day or two to drain. The trucks are then run out into a meadow, where the flax is taken out of the crates, and the bundles are opened and stood up in sheaves to dry and harden. The Legrand method has several advantages over the older methods. Owing to the regular manner in which the straw is treated, the flax is more even in strength and colour than that produced in other ways. Moreover, the time is reduced to three or four days, much less labour is required, and the process can be carried on all the year round without cessation. During recent years, a somewhat modified form of this process has been employed at certain factories in Belgium and Holland.

In the retting process, whatever method is employed, it is of great importance that the fermentation should be stopped at the right point, since over-retting weakens the fibre and increases the amount of tow, or "codilla," produced on scutching, whilst under-retting causes part of the gummy encrusting matter to be retained, and interferes with the subsequent manufacturing processes.

Various efforts have been made to replace the retting process by treating the straw with chemical reagents, such as dilute caustic alkali, but such methods have not yet proved successful on the large scale.

Methods have also been suggested for preparing the fibre by purely mechanical means without retting, but these involve the loss of much of the fibre, and yield a rough, hard product, which is of much poorer spinning quality than that obtained by the retting process.

Breaking.—The dry, retted stalks are passed between pairs of grooved or fluted rollers in order to break the woody core into small pieces. There are usually from six to twelve pairs of such rollers, which are so adjusted that each pair works more closely than the preceding pair.

Scutching.—The fragments of wood resulting from the "breaking" process are removed by scutching. The fibre is suspended in a machine which is provided with a revolving cylinder, or drum, bearing tough, flexible wooden blades on its periphery. As the cylinder revolves the blades strike the flax, and thus expel the broken wood, which is termed the "shieve" or "boon." The operation necessarily causes a considerable waste of fibre, some being broken by the scutching blades and some adhering to the shieve. This waste, known as "codilla" or "scutching tow," is used for spinning yarns for twines, canvas and other articles. Much ingenuity has been applied to the improvement of scutching machinery with a view to saving time and labour and to producing as little short fibre or codilla as possible.

Sorting and Baling.—After the flax has been scutched it is sorted into separate lots according to quality. It is then tied into small bundles, and afterwards packed into bales under pressure. The best qualities are covered with sacking, and each bale is marked to indicate its grade. Raw flax is almost invariably known in the market by the name of the district in which it is grown, and is further classed by special marks or letters to indicate the grade.

Production of Flax

With the exception of Asiatic Russia, flax cultivation for fibre is almost entirely restricted to Europe. An estimate of the production of the principal flax-growing countries during 1907–1913, as far as official data are available, is given in the following table, which has been adapted from the statistics published in the *Year-book of the United States Department of Agriculture.*

Producing Country.	1909.	1910.	1911.	1912.	1913.
	Tons.	*Tons.*	*Tons.*	*Tons.*	*Tons.*
Austria-Hungary	43,989	34,744	30,370	23,452	22,311
Belgium	12,050	22,320	23,214	28,571	17,606
Bulgaria	89	316	392	137	—
France	13,613	14,780	20,091	20,569	—
Italy	3,232	3,073	2,714	2,460	2,559
Netherlands	5,999	6,334	9,343	9,472	7,413
Roumania	727	1,986	2,022	3,995	2,125
Russia (European)	487,082	313,606	350,507	523,241	760,361
Russia (Asiatic)	43,036	—	—	—	—
Servia	491	980	933	935	—
Sweden	670	625	670	541	—
United Kingdom (Ireland)	7,179	8,876	11,241	12,956	12,652

The quantities and values of (1) flax, and (2) flax tow or codilla imported into the United Kingdom during the years 1912–15 are given in the tables on page 109.

Flax Cultivation in British Territory

Ireland and Canada are the only parts of the British Empire in which flax fibre is at present produced on a commercial scale.

Ireland.—The Irish flax-growing industry attained its maximum in 1864, when 301,693 acres were devoted to the crop, but subsequently it underwent a rapid decline, the lowest area on record being that of 1898 which amounted to 34,469 acres. Some improvement then took place, the average annual acreage being 48,064 acres during 1901–1905, and 49,169 acres during 1906–1910. The areas planted in the years 1911–1916 were as follows:

Year.	Area. *Acres.*	Year.	Area. *Acres.*
1911	66,618	1914	49,253
1912	55,062	1915	53,143
1913	59,305	1916	91,454

The principal cause of the decline in the industry was the speculative nature of the crop due to uncertainty of yield and price. It has been suggested that it was partly owing to a change having occurred in the climatic conditions, but there is no evidence that such a change has really taken place. The Irish flax-spinning industry has undergone great extension in recent years, and at present only about one-fourth to one-fifth of the fibre required in the mills is produced in the country, the remainder being imported.

Flax cultivation receives a great deal of attention from the Irish Department of Agriculture who have carried out experiments for several years past, particularly to ascertain the best seed for sowing and the best manures for the crop, and to produce improved

Imports of Flax (Dressed or Undressed) into the United Kingdom

	Quantity.				Value.			
	1912.	1913.	1914.	1915.	1912.	1913.	1914.	1915.
From	Tons.	Tons.	Tons.	Tons.	£	£	£	£
Russia	68,453	68,161	53,248	51,999	2,777,911	2,806,829	2,023,538	3,452,701
Germany	226	236	74	—	15,259	14,397	3,569	—
Netherlands	1,927	1,442	4,145	5,710	120,973	87,059	318,317	738,342
Belgium	16,205	14,194	13,987	1,105	1,421,529	1,262,141	1,234,713	150,961
France	252	99	1,091	3,199	12,587	4,621	66,274	287,502
Other countries	15	138	398	1,570	336	5,082	17,193	102,680
Total	87,078	84,270	72,943	63,583	4,348,595	4,180,129	3,663,604	4,732,186

Imports of Flax Tow or Codilla into the United Kingdom

	Quantity.				Value.			
	1912.	1913.	1914.	1915.	1912.	1913.	1914.	1915.
From	Tons.	Tons.	Tons.	Tons.	£	£	£	£
Russia	12,366	13,416	10,921	19,857	415,990	503,160	401,229	1,160,552
Germany	384	283	210	—	16,533	12,050	6,403	—
Netherlands	95	226	364	684	2,631	5,220	14,147	29,809
Belgium	5,465	3,812	2,363	66	102,150	65,335	55,536	2,697
France	111	179	213	220	1,031	1,848	5,485	5,247
Other countries	431	267	112	290	5,814	3,477	1,716	15,226
Total	18,852	18,183	14,183	21,117	544,149	591,090	484,516	1,213,531

varieties by a system of selection. They also give advice to the growers and endeavour to promote the industry in other ways.

Canada.—Flax has been grown for many years in the western part of Ontario, and certain other districts. The exports during 1910–1915 were approximately as follows :

Year.	Quantity. *Tons.*	Value. £
1910	592	26,084
1911	348	15,040
1912	118	5,037
1913	303	9,660
1914	336	7,131
1915	540	17,978

Almost the whole of these exports were consigned to the United States.

Other Countries.—Flax was at one time grown in certain parts of Great Britain, and an attempt is now being made to resuscitate the industry. For this purpose, an association has been formed under the name of "The British Flax and Hemp Growers' Society" which is being assisted by grants from the Development Commission. Flax is being cultivated at Selby, Yorkshire, where the industry was carried on extensively in the past, and also near Yeovil, Somerset, and experiments are being made in retting the stalks and preparing the fibre.

During the last three or four years efforts have been made to ascertain whether flax could be grown successfully in the East Africa Protectorate. Preliminary trials proved so satisfactory that in 1913 the services of a flax expert from Courtrai, Belgium, were secured, and it has been now demonstrated that flax of a high quality can be produced. A sample of the fibre was valued in London at £65 per ton, a price only £10 per ton below that of the best Belgian flax. Samples examined at the Imperial Institute also proved to be of excellent quality. The cultivation is being extended and a scutching factory has been erected at Lumbwa. All the work involved, except scutching, can be carried out by unskilled labour, and the industry is undergoing rapid development.

Flax was formerly an important crop in Egypt, but its cultivation declined as the cotton industry developed. Renewed attention has been given to the crop recently, and in 1916 it occupied about 12,000 acres.

There is no doubt that flax could be grown successfully in some other parts of the Empire. Experiments have been made in Cyprus, and the Transvaal and Orange River Provinces of South Africa: Trials on a more extensive scale have been carried out in Bihar, India, and it has been proved that flax can be grown and prepared successfully in that region at a profit of about £4 per acre; planters have not shown any readiness, however, to take up the cultivation owing to the uncertainty of prices and their disinclination to invest capital in a new industry. Experiments which have been conducted in Victoria, New South Wales, Queensland and Tasmania, have indicated that the soils and climatic conditions of these countries are suited to the requirements of the plant.

Structure, Uses and Properties of Flax Fibre

Flax consists of long filaments, each composed of a group of bast fibres. The length of the filaments varies from 12 to 36 in., and the diameter from 0·0018 to 0·025 in., with an average of about 0·006 in. The best flax is of a pale yellow colour; dew-retted flax is usually grey, and incompletely retted flax has a greenish tint. The fibre is soft, flexible, and lustrous, and is stronger and more durable than cotton; it is also a better conductor of heat than cotton, and it is for this reason that linen fabrics feel cold to the touch.

The finest kinds of flax are employed for the manufacture of linen fabrics, such as damasks, sheetings, cambrics, and for linen thread and lace, whilst the coarser qualities are used for canvas, hollands, bagging and twine.

The ultimate fibres of which the filaments are composed are of regular, more or less cylindrical, form and taper towards the ends. At occasional points in their length, joint-like swellings occur which commonly bear a cross-like marking and are termed "nodes." The walls of the fibres are so thick that the central cavity or lumen is either very small or almost obliterated, and to this peculiarity the remarkable tenacity of flax is due. The outer surfaces of the walls bear transverse markings, which are of value in preventing the fibres from slipping over one another in the spinning process, and also contribute to the durability of linen fabrics. The length of the ultimate fibres ranges from 0·3 to 1·5 in., and the diameter from 0·0005 to 0·001 in.

The yield of flax obtained in different countries varies from 8 to 20 per cent. of the weight of the rippled straw.

A few words may be added with reference to some of the chief commercial varieties. The Belgian grades are fine, long, and of excellent colour. Irish flax is renowned for its good colour, softness, and fineness. Italian flax is more lustrous than most other kinds. The best French and Dutch grades are also of very satisfactory quality. Russian flax is mostly of good length, but only of medium or low quality.

Commercial Value

The average prices of Belgian flax per ton in Belfast during the years 1905–1914 were as follows:

	£		£
1905	67	1910	73
1906	69	1911	87
1907	68	1912	88
1908	69	1913	89
1909	68	1914	88

Irish flax during the same period realised the following average prices per ton:

	£	s.		£	s.
1905 . . .	54	10	1910 . .	70	0
1906 . . .	56	10	1911 . .	68	10
1907 . . .	56	10	1912 . .	65	0
1908 . . .	51	0	1913 . .	57	10
1909 . . .	57	0	1914 . .	72	0

The following prices per ton were quoted in Dundee for Russian flax at the beginning of each of the years mentioned:

Petrograd Bejetsky

	£	s.		£	s.
1905 . . .	33	0	1910 . .	40	0
1906 . . .	40	10	1911 . .	47	0
1907 . . .	37	10	1912 . .	40	0
1908 . . .	36	10	1913 . .	45	0
1909 . . .	35	0	1914 . .	39	10

Riga Livonian Crowns

	£	s.		£	s.
1905 . . .	24	10	1910 . .	26	15
1906 . . .	27	10	1911 . .	32	15
1907 . . .	25	10	1912 . .	27	0
1908 . . .	20	0	1913 . .	32	0
1909 . . .	22	10	1914 . .	24	10

HEMP

Common or true hemp is derived from the stems of *Cannabis sativa,* a plant of the natural order Moraceæ, which grows wild in Central Asia, and is cultivated in many parts of the temperate and tropical regions of both hemispheres. The seeds of the plant contain about 30 per cent. of a useful oil. In hot countries the stalks, leaves and flowers produce a resinous juice, possessing properties which render it one of the most characteristic narcotics of Eastern lands. The drug is known under various forms, such as "charas," the resin itself; "ganja," the dried flowering tops of cultivated female plants;

"bhang," the dried leaves and flowering shoots of either or both the male and female plants; and "hashish," a Turkish preparation of the leaves.

The term "hemp" has unfortunately been applied to various fibres which differ greatly from true hemp; and this has led to great confusion, especially in statistical returns in which commonly no descriptive prefix is attached. Among the commoner fibres which bear the name of hemp may be mentioned Bombay, Sunn or San hemp (page 122), Deccan or Ambari hemp (page 146), Manila hemp (page 156), Sisal hemp (page 166), Mauritius hemp (page 181), bowstring hemp (page 185), and New Zealand hemp (page 187).

The common hemp plant is an annual, growing to a height of 4 to 10 feet or even more. The stem is erect, the flowers are small, yellowish-green and inconspicuous, and the fruit is a smooth, brownish-grey achene containing a single seed. The plants are of two kinds, one bearing male flowers and the other female flowers.

Hemp is cultivated for fibre in most European countries, and especially in Russia, Italy, Austria-Hungary, Servia, France and Germany. The plant occurs on both the east and west coasts of Africa. In the United States of America, it is grown in Kentucky and the neighbouring States, and it is also cultivated in Chile and Mexico. It is of common occurrence in India and is cultivated to a limited extent in Kashmir and the Himalayas, and is also grown largely in China and Japan.

Climate and Soil

The hemp plant requires a mild climate and a humid atmosphere, and grows best on rich, loamy soils containing a large quantity of humus. The sub-soil should be fairly retentive of moisture, or otherwise, in case of drought, the crop is liable to receive a check and the fibre consequently becomes harsh and woody. Light sandy soils and heavy clay soils are quite unsuitable.

Cultivation

The land is usually ploughed in the autumn and harrowed and rolled in the following spring. If the soil lacks fertility, it should be treated with a heavy dressing of farmyard manure, or a "green manure" crop should be dug in. Chalk, gypsum and potash manures are sometimes applied with advantage. Experiments in the United States have shown that nitrate of soda or sulphate of ammonia or a mixture of one of these salts with chloride or sulphate of potash has a very beneficial effect. The leaves and the refuse from the retting and scutching processes should be returned to the soil, and the same land may then be planted with hemp for several years in succession without becoming exhausted. Rotation with other crops is advisable however, and is essential if the crop has been attacked by the root-parasite, *Orobanche ramosa*, which sometimes causes considerable damage.

The seed is sown in the spring as soon as all danger from frost is over. The quantity of seed sown per acre varies according to the quality of fibre desired. For the production of fibre suitable for cordage or coarse textiles, about one bushel per acre is used, whilst if the finest hemp is required as much as 3 or 4 bushels per acre are sown. The seed is usually sown broadcast, but in the United States machine sowing in drills is commonly practised. After the seed has germinated, little cultivation is required beyond weeding during the early stages of growth and thinning out the seedlings if they come up too thickly. When the plants have reached a height of 8 inches, weeding may be discontinued.

If the crop is grown for fibre only, both male and female plants are harvested at the same time, but if both fibre and seed are desired, the male plants are first collected by hand-pulling, and the female plants are left for about 3 weeks longer for the seed to ripen. The male plants are ready for harvesting when their colour changes from deep green to light brown. The fibre from the male plants is said to be superior to that from female plants which have been allowed to produce seed. When both sexes are harvested together, the plants are either pulled by hand or cut with a kind of sickle. The method of pulling yields the more valuable product as when the plants are cut some of the best fibre is left in the stubble.

Preparation of Hemp

Hemp consists of the bast tissue surrounding the central woody column of the stalks. In order to free the fibre from the gummy or pectous substances with which it is encrusted and thus facilitate its removal, the stalks are subjected to the process of retting.

Before the stalks are retted they are sometimes dried. In Italy it is usual to lay them down in a fairly shady place, and allow them to remain exposed to the air for from four to six days, turning them over occasionally. In some districts the stalks are hung up on a sort of frame. The roots and ends of the stems are then cut off, and the branches and leaves are removed by beating with sticks. The stalks are subsequently sorted according to length, and made up into bundles, each containing ten or twelve. The bundles are placed root-end downwards in cone-shaped shocks to undergo further drying.

In France and some other countries the stalks are not dried before retting; but after the roots and tops have been cut off they are made into bundles, and retted immediately.

Retting.—This process consists essentially of submitting the stalks to the action of water so that a kind of fermentation is set up. For an explanation of this process, and an account of the changes involved, reference should be made to the section on flax (page 102).

Hemp is usually retted by one of three different methods, known as "water-retting," "dew-retting," and "snow-retting." The extent to which the retting is allowed to proceed has a great influence on the strength and pliability of the fibre; hemp intended for the manufacture of fine textiles should therefore be retted more than that for coarser goods, whilst fibre for cordage purposes should be retted least of all. The progress of the operation can be readily ascertained by drawing the thumb-nail along a stalk from the root-end to the top; when the fibre readily strips off the stem, the retting has proceeded to a sufficient extent. If the fibre is over-retted it is rendered weak and brittle, and it is therefore of the utmost importance that the stalks should be withdrawn at the right moment. For the accurate determination of this point a good deal of experience is necessary.

Water-retting is practised in Italy and in parts of France, and may be effected either by still or running water. Soft water gives the best results. Water containing iron must on no account be employed, as it causes the fibre to assume a rusty colour. The duration of the process depends on the temperature of the water, the state of the weather, and the quality of the hemp stalks, but is roughly from one to three weeks. If the atmospheric temperature is very high it is well to run off some of the water and replace it by a fresh supply. The retting water should not be used more than once if the best results are to be obtained; but if it cannot be changed, and has to be used for a second or third retting, its retting power is diminished, and the resulting fibre is usually of inferior quality and has a green colour. In some cases the retting is carried out in pools or ditches, 3 or 4 ft. deep and of varying length and breadth. The bundles of hemp are laid at the bottom of the pool, covered with straw or sods, and loaded with stones or logs of wood. Standing water is said to yield softer fibre than running water; the colour of the product in the former case is inferior, but it can be improved by subsequent treatment. In some hemp-growing districts the process is conducted in basins situated at different heights, so that a small stream constantly trickles down from one to another. In certain of the larger undertakings in Italy the ordinary pools or ditches are replaced by special retting pits or tanks, lined with oak-planks or with bricks, whilst in some parts of France pools lined and floored with cement are employed.

River-retting is considered in France to give better results than pool-retting. The bundles of hemp are floated in the stream, and covered with boards loaded with stones.

After the retting is finished the stalks are washed with fresh water and dried by exposure to the sun and air. In Italy the bundles are opened and the stalks are stood on the grass, root-end downwards in pyramidal shocks. In certain other countries the hemp is spread out evenly in a field, and left for three weeks or more, being turned over with light wooden poles every three or four days. If showers of rain occur during the drying period, considerable injury is likely to be effected, as the fibre is caused to lose a good deal of its lustre and to become harsh. In order to avoid accidents of this kind the stalks are sometimes dried at a moderate temperature in bakers' ovens or in brick-kilns. When the hemp is quite dry it is tied up again in bundles, conveyed to a barn or rick, and kept as dry as possible until required for the further processes of preparation.

Dew-retting is generally adopted in the United States and in parts of France. The stalks, after being allowed to stand in shocks for a few days, are spread out carefully in long rows in the fields of stubble from which they have been cut, or on closely cropped pasture land. They are here subjected to the action of the rain and dew for a period varying from two to ten weeks, and are turned over at intervals. If necessary an occasional watering may be given. In warm, rainy weather the hemp is liable to ret somewhat rapidly, and the risk of loss is thereby increased, as it is often difficult to turn the stalks whilst the rains continue. The result is that the fibre becomes retted unevenly, and much of it may be over-retted. The occurrence of light, warm showers soon after the hemp has been spread out, however, is of value to start the retting process. It is considered in the United States that although water-retted hemp is of lighter colour and finer texture and commands higher prices than the dew-retted fibre, it is nevertheless not so remunerative, as it requires a large amount of labour and the use of expensive retting tanks.

Snow-retting is sometimes practised in Russia and Sweden. After the first fall of snow, the dried hemp-stalks are spread out and allowed to be covered by subsequent falls. They are left until the spring, and then, after the snow has melted, are generally found to be sufficiently retted.

The process of extracting hemp in Japan differs widely from the three methods described above. The stalks are tied into bundles, submitted to the action of steam for a few minutes, and then dried in the sun. They are subsequently dipped into water, and again exposed to the sun for a few days. The bundles are now thoroughly wetted by plunging them into water, and are then heaped on a thick layer of straw mats in a barn and allowed to undergo a moderate fermentation. The arrangement of these heaps and the regulation of the fermentative process so as to obtain the best results demand considerable skill. After the fermentation has proceeded to a sufficient extent the fibre is stripped off by hand and immersed in water. The epidermal tissue is removed by scraping the product by hand with a special implement, and the fibre is hung on bamboos to dry in a well-ventilated barn. The product obtained by this means consists of thin, smooth, pale straw-coloured ribbons.

Breaking and Scutching.—These processes are carried out in a very similar manner to those described in the case of flax (page 106). The greater part of the hemp of commerce is broken by wooden hand-breaks. The woody core of the stalks is crushed between the heavy jaws of this implement, and the "boon" or "shieve" is afterwards removed by a simple beating or scutching process. Sometimes breaking machines, composed of one or more pairs of fluted rollers, are employed.

Production, Yield and Commercial Value

The approximate quantities of fibre produced in the principal countries where hemp is systematically cultivated are given (so far as statistics are available) in the following table :

	1910.	1911.	1912.
	Tons.	*Tons.*	*Tons.*
Austria	14,811	14,043	14,746
Bulgaria	1,064	1,109	—
Chile	683	93	269
France	12,936	14,396	13,640
Hungary	60,060	50,137	—
Italy	85,444	66,268	93,375
Japan	8,972	9,423	—
Roumania	2,403	2,336	1,879
Russia (European)	262,677	243,129	356,384
Russia (Asiatic)	32,662	22,057	34,881
Servia	.	6601 (1908)*	

* More recent figures not available.

The imports of Italian and Russian hemp into the United Kingdom during 1911–1915 were as follows :

	1911.	1912.	1913.	1914.	1915.
Italian :					
Quantity (*tons*)	10,343	7,881	9,102	15,258	25,004
Value (£)	372,416	342,091	376,044	620,984	1,259,701
Russian :					
Quantity (*tons*)	12,579	13,764	12,818	7,679	5,321
Value (£)	384,976	458,752	432,201	284,370	260,368

The quantity of dry stems produced per acre is usually about 2 or 3 tons. The yield of hemp amounts to about 25 per cent. of the dry stalks, and the product when combed furnishes about 65 per cent. of spinning fibre, the remainder being obtained in the form of tow.

The commercial value of hemp depends to a large extent on the colour and lustre. The nearly white and pale grey are regarded as the best, the greenish-coloured next, whilst the soft yellowish kinds are the least valuable.

The best hemp of commerce is the Italian variety, especially the Bolognese product, which is distinguished by an excellent colour, a silky lustre, a length of 6 ft. or more, and a flax-like softness. Next to Italian hemp stands the French fibre, particularly that of Grenoble. The Russian kinds are rather coarse, but are of great strength and durability. The hemp of the United States generally resembles that of Russia.

The prices of certain well known grades of Italian and Russian hemp in London during the years 1903–1912 were as follows: The average price of Italian P.C. varied from £30 (December 1903) to £59 per ton (October 1911). Italian S.P.S. varied from £24 (December 1903) to £41 per ton (October 1911). The price of Russian F.S.P.R.H. ranged from £25 10*s.* (July–October 1904 and May 1905) to £40 10*s.* (December 1912), the average being £31 per ton. During 1913 and 1914 (prior to the outbreak of war), Italian P.C. fluctuated between £39 and £46, Italian S.P.S. between £27 and £31, and Russian F.S.P.R.H. between £39 and £41 per ton. In 1915, prices for Italian P.C. were from £45 to £57 per ton.

Structure, Properties and Uses of Hemp Fibre.

Hemp appears in the market as narrow, ribbon-like strands of a length varying from 3 to 6 ft. The colour of the product depends on the manner in which it has been prepared and dried, and may be nearly white, of a straw tint, green, brown, pale or deep grey, or nearly black. The fibre is very strong and durable, and is not rotted by water. It cannot be bleached satisfactorily, and is therefore generally used in the unbleached state. Hemp is longer, more rigid, and coarser than flax; it does not consist of such a pure form of cellulose as the latter, but is more cuticularised. On account of its lack of elasticity and flexibility, it is rarely used for the manufacture of fine textiles.

The ultimate elements of which hemp is composed appear under the microscope as prosenchymatous cells or fibres of somewhat irregular shape; at certain points in their length they are flattened, and at other places cylindrical. The cell-wall is much more variable in thickness than that of flax. The fibres vary in length from 0·2 to 2·2 in., with an average of about 0·9 in.; and in diameter from 0·0005 to 0·0015 in., with an average of 0·0007 in. The lumen is generally fairly wide, but becomes narrower towards the end of the fibre and is practically free from cell-contents. The surface of the fibre bears numerous striations, but does not present nodes such as are visible in the case of flax. The fibres are forked at the ends, and this character enables hemp to be readily distinguished from flax.

The chief uses to which hemp is applied are the manufacture of ropes, cables, twine, nets, sail-cloth, canvas, and tarpaulins. The fibre is also used for the warps of carpeting materials.

SUNN HEMP

Sunn or San hemp, known also as Bombay hemp, is exported from India in fairly large quantities, and finds a market as a substitute for true hemp. It consists of the bast fibre of the stem of *Crotalaria juncea*, a plant of the natural order Leguminosæ, which is cultivated in India and Ceylon and grows to the height of 6–10 ft.

The plant can be grown most satisfactorily in districts of moderate rainfall. It requires a light soil, and grows well on a moderately deep soil which is fairly retentive of moisture. It cannot be grown on clay, and, if cultivated on a very rich soil, it is liable to produce coarse fibre of poor quality.

The methods employed in different parts of India for the cultivation of *Crotalaria juncea* and the extraction of the fibre vary a good deal, but the following may be regarded as fairly typical of the best practice. Before sowing, the ground must be brought into a good state of tilth by ploughing and repeated harrowing. Sowing is generally carried out at the

From the Collections of the Imperial Institute

SUNN HEMP PLANT (*Crotalaria juncea*)

Godaveri District, Madras

From the Collections of the Imperial Institute

FIELD OF SUNN HEMP

Godaveri District, Madras

commencement of the rainy period (June or July). The seed is either sown broadcast or planted by means of a drill, the amount used being about 70 lb. per acre. After the seeds have germinated, no further attention is required until the collection of the crop which takes place from 4 to 5 months after sowing. The plants should be 3 or 4 inches apart in each direction.

Harvesting is usually effected during the flowering stage but, in some cases, is deferred until the fruit has been formed. The plants are generally uprooted from the soil, but sometimes they are cut off close to the ground by means of a sickle. The stems are allowed to dry and the leaves and fruits are then removed. It is preferable, however, at any rate in humid regions, to treat the crop immediately after it has been gathered, without permitting it to become dry.

The fibre is extracted by means of a retting process, similar to that employed in the case of jute (page 135). The stems, tied up in bundles, are placed in pools of water and kept submerged by being loaded with stones or logs of wood. Retting is usually complete in India in about five days, but a longer time is required in cold weather. The bark is then stripped from the stems, and the strips are cleaned by beating them with sticks and dashing them repeatedly against the surface of the water. When the fibre is quite clean, it is squeezed to remove the water and then hung on lines to dry.

The yield of dry stems usually amounts to 3 or 4 tons per acre; the dry stems furnish about 8 per cent. of their weight of clean fibre, and hence the quantity of fibre obtained per acre is about 5 or 6 cwts.

Sunn hemp resembles European hemp in appearance, but is not quite so strong. It consists of narrow, ribbon-like strands about 4 or 5 feet long, with a colour varying from grey to pale yellow. The fibre is only slightly lignified.

The ultimate fibres of which Sunn hemp is composed are approximately 0·2–0·4 inch long, and have an average diameter of about 0·0012 inch. The fibres do not taper to a point, but the ends are thickened and rounded.

The value of the fibre in the London market, where it is known as "Bombay hemp," depends on the colour, length and other characters, and usually varies from about £15 to £30 per ton.

RAMIE, RHEA, OR CHINA GRASS

The fibre known as ramie, rhea, or China grass is obtained from the stem of a plant of the natural order Urticaceæ, or nettle family, which grows to the height of 4 to 8 feet, and in appearance, habit and growth somewhat resembles the common nettle, *Urtica dioica*, but is devoid of stinging hairs.

There are two varieties of the plant. One of these, the China grass plant, which has been cultivated by the Chinese from very early times under the name of "ch'ü ma," is known botanically as *Boehmeria nivea*. The distinguishing characteristic of this form is the presence of numerous, short, silvery hairs on the under-side of the leaves which gives them a white, felted appearance. The other variety, which is termed "rhea" in the islands of the Malay Archipelago, is known as *Boehmeria nivea* var. *tenacissima* or the green-leaved China grass. It closely resembles the Chinese plant, but the leaves are green on both sides.

The true China grass plant is cultivated chiefly in China and Formosa, whilst *B. nivea* var. *tenacissima* is adapted to growth in tropical countries, such as the Malay Islands and Mexico. The Indian plant has been stated by many writers to be the form *B. nivea* var. *tenacissima*, but Sir George Watt, who has made a special study of this question, affirms that it is the same variety as the Chinese plant.

The fibre is derived from the inner bark or bast tissue of the stems.

Cultivation

The ramie plant is easy to cultivate, and thrives in almost any soil, but is especially adapted to a naturally rich, moist soil of a light loamy character. In China it is usually grown on a red clay containing sand. In the United States it has been cultivated experimentally on a great variety of soils, and it has been found that the plant grows best on light, sandy, alluvial soils, although it will flourish on any good soil which is capable of retaining its moisture throughout the growing season. In order that the growth of the stems may be rapid and continuous, a hot, moist, and equable climate is required.

The ramie plant withdraws from the soil a large quantity of valuable constituents. As only a small proportion of these materials is contained in the fibre it must be advantageous, on general principles, to return as much as possible of the refuse of the crop to the land. Experience has shown that without liberal manuring the yield of fibre diminishes, and that the application of organic manures, such as liquid manure, farmyard manure, guano, or oil-cake, is very beneficial. These fertilisers can sometimes be supplemented with artificial manures.

The propagation of the ramie plant is effected by means of seed, cuttings, or layers, or by division of the roots. When the plant is grown from seed, it is usual to sow it in the hot-bed and to transplant the seedlings after five or six weeks' growth. The method of growing the plants from cuttings is practised in some parts of India. The stems are cut in the spring, only the portions which have turned brown being employed for the purpose. The cuttings usually include three buds, a margin of a quarter of an inch being allowed at each end beyond the top and bottom buds respectively. When the plant is propagated from root cuttings, the young lateral shoots with their roots are cut off and planted about a foot apart in furrows four inches deep.

The amount of moisture supplied to the plants during their growth must be carefully regulated. If an excess of moisture is present the plant grows rapidly but produces a fibre of poor quality. If, on the contrary, the plant is unable to obtain sufficient water, its growth is retarded and it becomes stunted. When these two opposite conditions both occur during one season, the plant yields a fibre of mixed quality and irregular strength, which is liable to suffer considerable loss in its extraction and preparation for spinning.

Preparation of the Fibre

The methods of preparing ramie fibre differ considerably from those employed in the case of flax and hemp. The encrusting substances are not removed by a retting process, but are extracted by chemical treatment.

The fibre known in commerce as "China grass" is prepared in China entirely by hand. The stems are first stripped, and the outer skin is removed by scraping and washing, different methods being employed in different parts of the country. The process is tedious and expensive, as the preparation of a few pounds of the ribbons constitutes a day's work. In the resulting product the fibres are firmly embedded in a gummy substance of a pectose-like nature, which must be removed before the fibre can be spun into yarn. The operation of degumming is not carried out in China, but is effected subsequently in Europe by chemical means.

The preparation of China grass by hand-stripping can only be made remunerative in countries where labour is exceedingly cheap and plentiful, and consequently numerous attempts have been made to invent suitable decorticating machinery. In 1869, the Government of India offered a reward of £5,000 for the best machine for decorticating the green stems, and a trial was held in 1872. No machine, however, completely fulfilled the requirements, and the full prize was not awarded. The reward was again offered, and a second official trial took place in 1879, but with no greater success. The effect of these competitions was to stimulate invention, and, in consequence, numerous decorticating machines have been produced, but many of them have given very disappointing results. A gradual improvement, however, has taken place, and, at the present time, the difficulty of decorticating ramie stems by machinery may be regarded as solved.

Ramie machines are of two kinds, namely, those that merely strip the bark in ribbons from the stems, and those that not only do this but further make some attempt to remove the outer layer from the ribbons. Machines of the first kind usually consist of rollers which crush the stems, and beaters which separate the woody portion from the bark. Those of the second class possess also some mechanism by which a scraping effect is produced on the strips of bark, and the material prepared in this way resembles hand-cleaned China grass.

The fibre having been separated from the stems in the form of strips or ribbons, the next stage in its preparation is the process of degumming. The object of this operation is to dissolve and wash out the gummy substances without attacking the cellulose; the epidermis becomes detached in the process, and may be removed from the fibre by washing. Many methods have been invented for degumming ramie fibre, and satisfactory processes have now been obtained, but, as a rule, the details are not published or patented, but are jealously guarded by the manufacturers. The following description will serve as an indication of the kind of treatment to which the material is subjected. The ribbons are boiled in dilute soda, are then exposed to the action of solution of bleaching powder, and are afterwards immersed in a bath of dilute acid, the two latter processes being repeated until the whole of the gum has been extracted. The result of this treatment is the production of a white, lustrous fibre known as the "filasse."

On account of the liability of injury to the fibre by the use of too severe treatment in degumming, ramie spinners usually prefer to buy the fibre in the form of ribbons, particularly of the hand-cleaned China grass, and degum it by their own process.

Yield

From two to four or even six cuttings of the stems can be obtained annually according to the climate and other conditions of the locality in which the crop is grown. It is estimated that from two cuttings the yield of fresh stems per acre amounts to about 15 to 20 tons, giving $\frac{3}{4}$–1 ton of dry ribbons. The ribbons furnish about 50 per cent. of their weight of degummed fibre or filasse, and hence the yield of filasse per acre amounts to approximately $7\frac{1}{2}$–10 cwts. per annum.

Characters and Uses

Ramie fibre is one of the strongest known. It is extremely durable, and is said to be less affected by moisture than any other fibre, but is somewhat lacking in elasticity. The fibre has a brilliant, silky lustre, can be dyed readily, and is exceptionally long. The filasse consists of isolated ultimate fibres or small groups of fibres. The ultimate fibres vary from 3 to 16 inches in length, and from 0·0008 to 0·003 inch in diameter, the average diameter being about 0·0015 inch or about twice as great as that of cotton fibre. The fibres taper towards each end, but the ends themselves are rounded. They are thick-walled, have a well-marked lumen and bear longitudinal striations and occasional transverse markings. The fibre substance consists of non-lignified cellulose.

Ramie fibre offers certain difficulties in the processes of manufacture, one of which is its tendency to cling to the rollers in the operations of drawing and spinning. At one time, manufacturers attempted to spin the fibre with machinery suitable for cotton, wool, or flax, but these efforts ended in failure. It was realised eventually that success in ramie spinning could only be attained by the use of machinery specially adapted to the manipulation of the fibre. Such machines have now been invented, and their employment has rendered it possible to utilise ramie fibre with commercial success.

China grass is used extensively in China for the manufacture of fabrics known as "grass-cloths." It could be used for the manufacture of many materials for which cotton, wool, or flax is now employed. It has been used successfully in combination with wool for the production of certain classes of fabrics. The fibre is woven into goods of various descriptions, such as lace, curtains, handkerchiefs, tablecloths, counterpanes, plush, carpets, and even clothing materials. It is also employed for the manufacture of mantles for incandescent gas lighting, and is said to furnish an excellent paper-pulp suitable for making bank-notes.

Most of the ramie fibre at present employed in Europe is imported from China. Experiments have shown, however, that the plant is capable of growth in most British Colonies and Dependencies, and that it could be cultivated on a large scale if the demand for the fibre were sufficient to warrant such an undertaking. With regard to West Africa, successful experiments were carried out at Kangahun in Sierra Leone in 1909. Scraped ribbons of 3 to 4½ feet in length were produced, but these were not sufficiently free from the outer bark to be comparable with hand-cleaned China grass; ultimate fibres extracted from them at the Imperial Institute were found to be of normal character. The plant has also been cultivated with success in the Cameroons.

During recent years the value of hand-cleaned China grass in the London market has varied between £30 and £50 per ton, whilst occasional consignments of the so-called rhea ribbons, from which the outer bark has not been removed, have realised from £10 to £15 per ton.

The ramie industry has not yet attained very large dimensions. Planters hesitate to grow the crop on a commercial scale unless they can be assured of a market for it. Spinners, on the other hand, complain of the irregularity of supplies and the high price of China grass, and therefore do not feel justified in establishing special mills for the manufacture of ramie goods.

Other Nettle Fibres

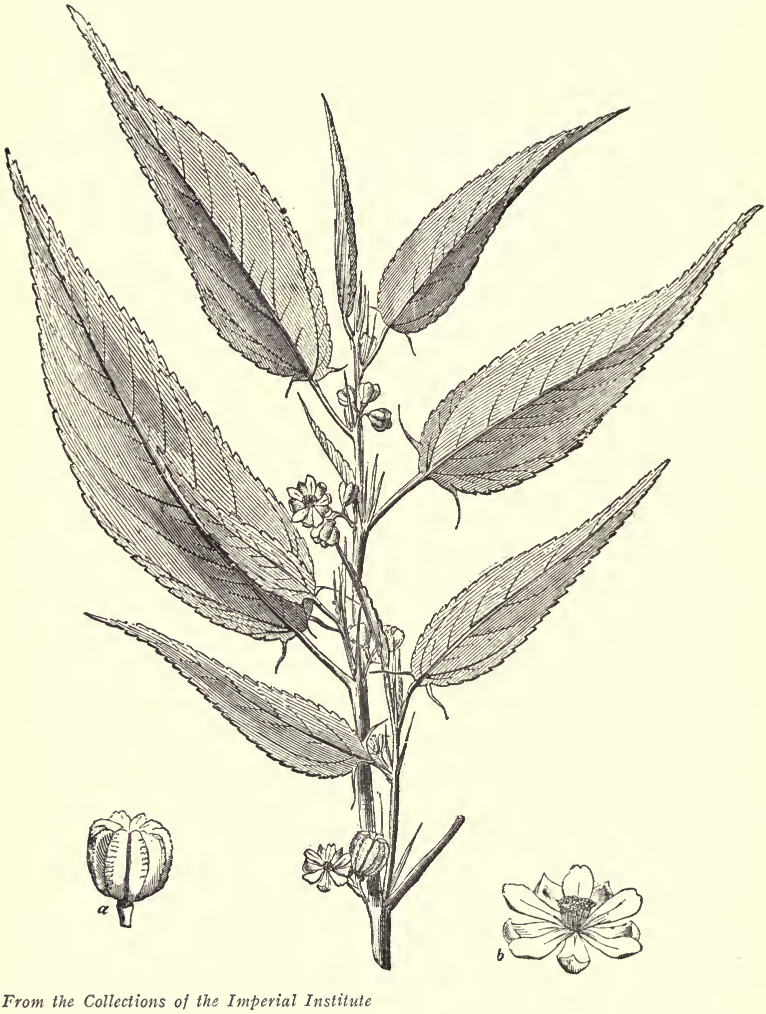
There are several other plants of the nettle family which yield fibres somewhat resembling that of ramie, and reference may be made to two Indian plants, *Villebrunea integrifolia* and *Girardinia heterophylla*.

The former plant, known as "ban rhea" (wild rhea), is a stingless nettle which grows wild on waste land, and yields a silky fibre, two or more inches long. It is stated that the bark contains less gummy matter than that of *Boehmeria nivea*, and that for this reason the fibre can be more easily extracted.

Girardinia heterophylla, the "Nilgiri nettle," is a tall plant provided with stinging hairs. It yields a soft, silky fibre, resembling ramie fibre in general character, but coarser and less lustrous. The ultimate fibres possess the remarkable length of from 6 to 20 inches.

Before the introduction of cotton into Europe, the fibre of the common stinging nettle (*Urtica dioica*) was used, especially in Germany and Picardy, for the production of yarns which were woven into the so-called "nesseltuch" (or nettle-cloth), which was capable of being bleached as white as linen. A few years ago, a method was devised for extracting this fibre on a commercial scale with a view to its utilisation for the manufacture of textiles. During the European war, renewed attention has been given to nettle fibre in Germany in order to compensate for the lack of cotton.

PLATE VII



From the Collections of the Imperial Institute

JUTE (*Corchorus capsularis*)

a. Capsule. *b*. Flower.

CHAPTER VI

JUTE AND SIMILAR FIBRES

JUTE is one of the cheapest fibres, and is used for the manufacture of coarse fabrics, such as sacking, hessians, horse-cloths and inexpensive carpets, and also for making inferior kinds of cordage. Practically the whole of the crop is produced in India. It was almost unknown to European commerce before the year 1830, although it had long been employed by the natives of Bengal for making twine and cloth.

THE JUTE PLANT

Jute is a bast fibre, that is, a fibre found between the bark and the inner woody portion of the stem; it is derived from two species of plants, *Corchorus capsularis* and *C. olitorius*, belonging to the natural order Tiliaceæ. These plants are annuals, grow to a height of 8 to 15 feet, and have long, straight, cylindrical stems, about ½–¾ inch thick, which do not bear any branches except near the summit. The leaves are about 2–4 inches long, about an inch wide towards the base, and gradually taper upwards until they end in a long, sharp point; the margins are coarsely serrated, and the base is prolonged into tail-like appendages. The flowers are yellow, and occur in groups of two or three together. The fruit of *C. capsularis* is a small, wrinkled, nearly globular, flat-topped capsule, whilst that of *C. olitorius* is a long, cylindrical, four- or five-celled capsule with an elongated beak. These differences in the form of the fruit are the chief distinguishing characters of the two species. There are numerous races of each of these species, and especially of *C. capsularis*, which vary in the colour of the stem and leaf-stalk, in the shape of the leaf, the height of the plant, degree of hairiness, size of flower, shape and number of valves of the fruit, and in the time of flowering.

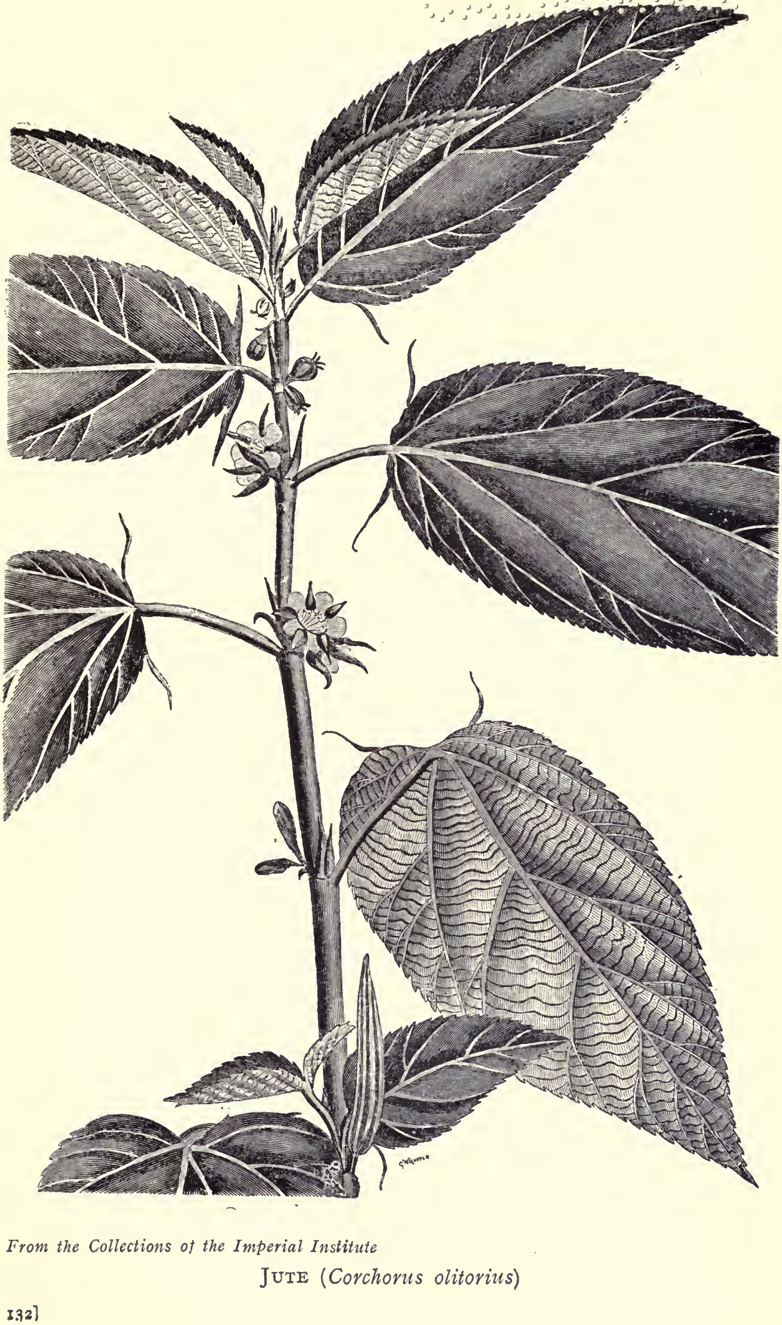
Each species possesses red- and green-stemmed races; it is said that the green form of *C. capsularis* yields the best fibre. *C. olitorius* is more widely distributed in India than *C. capsularis*, but is never cultivated when the latter can be grown, as it yields a less valuable fibre and takes longer to come to maturity.

Climate

Jute flourishes best in the hot damp climates and humid districts of the tropical and sub-tropical zones with a rainfall of 50 inches or more. After the plant has become well rooted, it is not injured by flooding of the land, and will even grow luxuriantly when half submerged in water. On the other hand, a swampy soil and excessive atmospheric humidity are by no means necessary; the crop can be grown with success on land that is never flooded, provided that the soil is kept moist by rain or irrigation. It is desirable, however, that there should not be much heavy rain, especially at the time of sowing and during the early part of the season. The best conditions are alternate sunshine and rain; excessive rain is not harmful after the plant has reached a height of two or three feet. When there is water standing at the roots or covering the land, the plants tend to produce surface roots, which injure that portion of the stem on which they arise and consequently render the fibre less valuable; drought, on the other hand, causes the plants to be stunted, and in dry districts the fibre produced is harsh, woody and brittle.

Soil

Jute can be cultivated on almost any kind of soil; but lateritic and open gravelly soils, and light sandy soils, are unfavourable. Clay soils give the largest



From the Collections of the Imperial Institute

JUTE (*Corchorus olitorius*)

yields, but it is said that the stems do not ret uniformly. Sandy soils produce coarse fibre. Rich loams, that is, rich mixtures of clay and sand, seem the best. In India, the finer varieties are cultivated on the higher lands on which rice, pulses, vegetables and tobacco are grown ; such crops are often rotated with the finer qualites of jute. The coarse and larger varieties are grown on alluvial deposits and islands formed by rivers, and also on the lowlands liable to inundation. The plant also grows on salt-impregnated soils, such as those of the Sunderbans.

Cultivation

The soil is broken up thoroughly and finely pulverised, heavy or clayey soils requiring more ploughing than lighter or alluvial soils ; the more thorough the ploughing the better the yield. In India, 4–12 ploughings are given with the primitive ploughs of the country, and at the last ploughing all weeds are collected, dried and burned. The land is sometimes hoed instead of being ploughed. The soil is also harrowed or the clods are broken up with a mattock. Manures are sometimes used when the seed is sown early. On lands, such as the rich alluvial areas in Eastern Bengal, which receive a deposit of silt each year from the rivers that inundate them, manuring is not usually necessary. In other cases, however, the continuous growth of the plant on the same soil renders it liable to become much branched, and this leads to a diminution in the length of the fibre. Jute is a somewhat exhausting crop, but the exhaustion can be remedied by manuring, by fallowing, or by rotation with other crops, such as mustard, rice, and pulses. The manures used are cowdung, oil-cake, rice-crop stubble, and ashes. Cowdung gives the best results, and should be applied in quantities of 2–5 tons per acre. The manure is spread on the land as evenly as possible and ploughed in before sowing. The return of the jute stems to the soil after the fibre has been extracted is of value as affording additional organic matter. Green manuring with

Sunn hemp (*Crotalaria juncea*), *Lathyrus sativus*, or *Phaseolus Mungo* is sometimes practised with good results.

The seed is sown between the middle of February and the end of June, according to the climatic and other conditions of the locality. The seeds are sown broadcast on a clear, sunny day, the soil having been sufficiently moistened by rain, and are then lightly covered to a depth of ¼ inch to 1 inch, either by hand, or by harrowing, or by drawing a wooden beam over the field. They must not be ploughed in deeply or left on the surface uncovered by earth. The amount sown is about 8–10 lb. per acre. The seed for sowing is usually obtained from a few plants allowed to mature the previous year in a corner of the field; it is of importance that the seed should be carefully selected.

Efforts are being made by the Agricultural Department of Bengal to improve the yield and quality of the fibre, and races of the plant have now been obtained which are decidedly above the average in both respects. Seed farms have been established in order to produce seed of these improved kinds in sufficient quantities to supply the needs of the cultivators.

When the plants have grown several inches or a foot high, the land is weeded and the plants are thinned out. The space left between the plants is usually 6 inches, but is sometimes 8–10 inches. It has been stated that spacing of 4–6 inches gives the best results. When the seed is sown sparsely, a better yield is obtained but the fibre is coarser.

Pests

The jute plant is sometimes infested by a small black weevil (*Apion* sp.) which feeds on the leaves. The insect breeds in the stems, in which the grubs bore tunnels, thus causing the plant to become stunted and withered.

A green semilooping caterpillar (*Cosmophila sabulifera*) has been observed on jute plants grown experimentally in Bihar. It attacks the terminal leaf-buds with the result that the growth of the main shoot is stopped.

Jute seedlings are sometimes attacked by ground grasshoppers.

Harvesting

The plants mature in three or four months, so that the crop sown in March is harvested in June and that sown in June is harvested in September or October. In India, the best time for cutting the crop is considered to be either when the plant is in flower or just after the appearance of the capsules, the fibre obtained at these periods being of superior quality. It is usually considered that fibre obtained from plants which have not flowered is liable to be weak, whilst that from plants in seed is harsh and deficient in lustre. Late cutting gives a woody and inferior fibre.

Jute is usually harvested by cutting the stems near the root by means of a bill-hook or sickle with a toothed edge; when the land is under water, boys sometimes dive in with a sickle to cut the crop, and the retting heap is built on the spot. On swampy and submerged land the crop instead of being cut is sometimes pulled up. The stems are made into bundles, each containing as much as a man can carry; sometimes the tops are cut off and the leaves removed before retting, but this is not always done.

Preparation of the Fibre

As has been already stated, the fibre is located between the bark and the central woody cylinder of the stem. In order to free it from these and obtain it in a form in which the individual strands are distinct from one another, the process of retting is employed. The stems are immersed in water, and allowed to remain until the fermentation set up has converted the gummy or pectous substances by which the fibres are bound together into soluble decomposition products. The latter are carried away by the water, and when the fermentation has proceeded far enough the fibre can be easily separated. In some districts, the crop is stacked for two or three days before retting, whilst in others the stalks are made into bundles and immersed in water immediately after reaping. They are sometimes immersed in running water, but more often in stagnant ponds ; the former plan is said to give the best fibre, especially as regards colour. The bundles are covered with a layer of refuse tops of the jute or of other plants, or with clods of earth or logs of wood, in order to make them sink; stones are preferable to earth as being less likely to injure the colour. It is stated that the stems should be covered so as to be protected from direct sunshine. In some places, the bundles are turned over during the steeping.

The time required for satisfactory retting varies with the age of the plants, the temperature of the water, and with other conditions, and lasts from a week or ten days to a month or even more ; after the right point is reached, further retting is injurious to the fibre, so the pools must be visited daily and the conditions of the stems examined to see whether the fibre separates properly. When the retting is far enough advanced the bundle is unfastened, and the cultivator, standing up to his waist in the water, having first removed adventitious roots, loosens portions of the fibre at the end of the stems, and grasping these he skilfully strips off the whole from end to end without breaking either stem or fibre. When a certain amount of fibre has been stripped off, he washes it by taking a large handful, swinging it round his head, dashing it repeatedly on the surface of the water, and drawing it through the water so as to wash off the bark ; he then spreads it out on the surface of the water, and carefully picks off any pieces of bark which still remain. It is then wrung out so as to remove as much water as possible and hung on lines to dry. It is said that jute dried in the shade is of a better colour than that dried in the sun.

The operations vary somewhat in different localities ; the fibre is sometimes loosened by means of a wooden beater before separating it from the stem, and a thick plank or heavy piece of wood held firmly in position by posts driven into the bed of the pond is recommended as facilitating the washing process by offering something more resistant than water to dash the root-ends of the plant against, these being less perfectly softened by the retting than the upper parts.

These primitive methods yield an exceptionally pure product, and the retting accomplishes the separation of the strands of bast fibre. Great care is required in the retting operation. If under-retted, the fibre is gummy and in the form of ribbons, whilst if over-retted the product is weak and deficient in lustre. The process has not yet been superseded by machinery. The average yield is a little over 1,200 lb. per acre, but double this quantity is sometimes obtained.

When thoroughly dry, the jute is made up in bunches of as much as can be conveniently held in one hand; these are doubled in the centre and taken in bundles to the market, where they are sorted according to quality and colour, and then packed in bales for export. The best portions of the crop are exported as "jute proper," the lower grades of the fibre are sold as "rejections," and the hard woody root-ends are known as "cuttings." In Calcutta the bales for export are made by means of hydraulic presses and weigh about 400 lb. each.

Characters, Structure and Uses of Jute

Jute consists of strands of fibre varying from 5 to 8 feet in length. It is usually of a pale yellow or yellowish-brown colour and possesses an excellent lustre. Each strand is composed of a large number of ultimate fibres, varying from 2 to 5 mm. (0·08 to 0·2 inch) in length and from about 0·02 to 0·025 mm. (0·0008 to 0·001 inch) in diameter. A transverse section of a filament of jute shows from about 8 to 20 ultimate fibres of more or less polygonal outline. These ultimate fibres are thick-walled but have a fairly wide lumen. Their surface is smooth and free from transverse markings such as are borne by flax fibres.

Jute differs considerably from cotton, flax and hemp in chemical composition. It consists of a highly lignified form of cellulose, whereas the other fibres mentioned are composed of a more or less pure form of this substance. A specimen of "extra fine" Calcutta jute, examined at the Imperial Institute by the methods described on pages 2–6, gave the following results: moisture, 9·6 per cent.; ash, 0·7 per cent.; loss on α-hydrolysis, 9·1 per cent.; loss on β-hydrolysis, 13·1 per cent.; cellulose, 77·7 per cent.

Jute is much weaker than flax or hemp and is not nearly so durable. It can be dyed with ease and is capable of combining directly with basic dyestuffs. It cannot be satisfactorily bleached, as treatment with bleaching powder and alkalis renders the fibre weak and brittle. The fibre is very susceptible to the prolonged action of water and rapidly undergoes deterioration. It is stated that jute rarely arrives in the United Kingdom in as good a condition as that in which it leaves India. This is considered to be due to a renewal during transit of the incipient fermentation set up in the fibre during the retting process. It not uncommonly happens that the fibre at the centre of a bale becomes quite rotten, and is then said to have suffered "heart damage." The cause of this injury is attributed to a large extent to the fraudulent practice of watering the jute before shipment.

The fibre is employed in the Calcutta mills chiefly for making the coarser classes of jute fabrics, especially gunny cloth and gunny bags, whilst in Dundee it is used for the manufacture of hessians, bagging, tarpaulins, sacking, carpets, rugs, matting, and backing for linoleums and oil-cloth.

The fibre at the base of the jute stem is hard and coarse. It is therefore customary to cut off about 6–8 inches from the lower end of the fibre before baling it, since if this portion were allowed to remain it would reduce the spinning quality of the material. These "root-ends" or "butts" are baled separately and are sold for paper-making.

Commercial Varieties and Prices

Jute is grouped commercially in four main classes, known as Serajgunge, Naraingunge, Daisee and Dowrah. Serajgunge is soft and from white to grey in colour. Naraingunge is of a darker colour than Serajgunge, ranging from pale buff to reddish-brown; it is of good strength and excellent spinning quality. These two varieties are employed for the manufacture of the best jute yarns. Daisee is dark-coloured, but is soft, long, and of good quality, and is largely used for making carpet yarns. Dowrah is strong but harsh and of inferior quality. Each of these classes is graded according to quality and colour, and receives a corresponding baler's mark.

The market price of jute is subject to severe fluctuations. This may be illustrated by reference to the prices per ton of "first native marks" (a fibre of medium quality) in December of each of the years 1903–1916.

	£	s.		£	s.
1903	12	15	1910	19	15
1904	16	0	1911	20	0
1905	19	10	1912	25	10
1906	28	0	1913	35	10
1907	16	10	1914	18	10
1908	14	15	1915	26	10
1909	13	15	1916	42	0

Production and Export

The area devoted to jute in India is approximately 3 million acres, and the average annual production amounts to about 1½ million tons. The official statistics for the years 1906–7 to 1913–14 are as follows:

Year.	Area. *Acres.*	Production. *Tons.*
1906–07	3,523,558	1,629,900
1907–08	3,942,675	1,753,200
1908–09	2,835,453	1,126,950
1909–10	2,756,820	1,286,900
1910–11	2,828,669	1,416,450
1911–12	3,090,827	1,470,480
1912–13	3,323,951	1,700,320
1913–14	3,137,165	1,588,200

About one-half of the total crop is now consumed in the Indian jute mills, the remainder being exported.

The following table gives the quantities and values of the total exports, and exports to the United Kingdom, during 1908–09 to 1914–15.

Total Exports

Year.	Quantity. Tons.	Value. £
1908–09	893,995	13,223,037
1909–10	730,418	10,058,873
1910–11	636,623	10,326,649
1911–12	810,155	15,037,734
1912–13	876,294	18,033,782
1913–14	768,451	20,550,929
1914–15	505,095	8,606,802

Exports to the United Kingdom

Year.	Quantity. Tons.	Value. £
1908–9	337,937	5,601,794
1909–10	297,799	4,289,508
1910–11	234,719	3,885,292
1911–12	345,762	6,530,513
1912–13	340,673	7,352,171
1913–14	290,369	7,826,358
1914–15	265,580	4,495,943

Nearly the whole of the crop is produced in Bengal. Of the 3,323,951 acres planted in India in 1912–13, no less than 2,927,100 acres were in Bengal whilst 298,500 acres were in Bihar and Orissa and 98,300 acres in Assam. The fibre exported in 1913–14 was shipped from the different Provinces in the following quantities : Bengal, 746,439 tons ; Bombay, 9 tons ; Madras, 22,003 tons ; total, 768,451 tons.

The exports in 1913–14 were distributed to the following countries :

	Tons.		Tons.
United Kingdom	290,369	France	72,708
Germany	158,380	Austria-Hungary	45,727
United States of America	117,744	Italy	37,770
		Spain	21,181

	Tons.		Tons.
Russia . .	9,086	Uruguay . .	179
Belgium . .	4,617	Hong Kong .	111
Japan . .	3,703	Formosa . .	7
Brazil . .	3,594	Ceylon . .	5
Holland . .	1,425	Straits Settlements	5
Argentina .	900		
Greece . .	564		
Australia . .	376	Total . .	768,451

Jute Manufacturing Industry

Jute was used by the natives of Bengal for making cordage and gunny cloth long before its introduction into European industry; the cloth was woven by means of hand-looms.

In Great Britain, attention was first directed to the fibre at the end of the eighteenth century, and early in the nineteenth century it was spun and woven in Abingdon. Small quantities of jute continued to be imported into the United Kingdom for several years, but it was not until 1832 that the utilisation of the fibre acquired any great importance. About this time, experiments were carried out in Dundee, which led the way to the development of an enormous industry. The success achieved is said to have been largely due to the use of whale oil to soften the fibre and thus facilitate its spinning. The growth of the industry was stimulated by the Crimean war of 1854–55 and the consequent diminution in the supply of Russian flax and hemp.

The progress made in Dundee in spinning and weaving jute by means of machinery led to the introduction of mills into the neighbourhood of Calcutta. The first jute mill was erected in 1854, and from this time forward the Indian jute manufacturing industry has steadily increased at a remarkable rate. During the period 1901–2 to 1913–14, the number of jute spindles increased from 331,382 to 744,289, the number of looms at work from 16,119 to 36,050, the number of mills from 36 to 64 and the number of persons employed from 114,795 to 216,288.

Extension of Cultivation

The whole of the world's jute supply is furnished by India with the exception of comparatively insignificant quantities produced in other countries. The plant is grown to a limited extent in Mexico, Egypt and China, and has been introduced into the United States of America. Successful experiments have recently been made in the Anglo-Egyptian Sudan and in West Africa.

Efforts are being made to extend the cultivation in India to other Provinces than Bengal and Assam, and certain irrigated tracts in the Punjab, Central Provinces and Madras are regarded as affording favourable conditions for the purpose. In all these places, however, the facilities for the cultivation are less favourable than in Bengal, and it is considered unlikely that under present conditions the industry will be undertaken on an extensive scale outside Bengal, Bihar and Assam.

An account of attempts to establish jute cultivation in British West Africa is given in the following paragraphs. So far the attention given to cotton and other agricultural crops has interfered with progress in this direction.

Jute Growing in West Africa

From the facility with which the jute plant can be cultivated and its fibre extracted, it seems very probable that there are numerous localities in West Africa suitable for its cultivation and that the natives would soon be able to acquire the method of preparing the fibre for the market. The crop would not prove a rival to cotton since it can be grown on land quite unfitted for the cotton plant. There are large areas in which the climatic conditions appear likely to be well adapted to the growth of the plant. The lower reaches of the Niger and the lagoon country of Nigeria seem to be particularly favourable.

Jute was first cultivated experimentally in West Africa in 1896, when large quantities of seed were supplied to several places on the coast. The experiments demonstrated that fibre of a good quality could be produced in the country, but they were on too small a scale to show whether a successful industry could be established on commercial lines. In 1905, in consequence of the increasing utilisation of jute in India and the consequent difficulty experienced by the jute spinners of Dundee in obtaining adequate quantities of their raw material, the Dundee Chamber of Commerce endeavoured to introduce the cultivation into British West Africa. Early in the year 1906, arrangements were made by the Colonial Office with the Government of India for a supply of Indian jute seed for distribution in the West African Possessions, and a Memorandum on the cultivation and preparation of the fibre drawn up by the Inspector-General of Agriculture, India, was communicated to these countries. It was proposed that experiments should at first be carried out on a small scale in order to ascertain the adaptability of Indian jute to West African conditions.

Gambia.—An experimental trial was made in the Gambia in 1897. The fibre produced was strong, of good spinning properties, well prepared, and was classed as being of medium quality and quite marketable; it was rather short, however, on account of the season of growth having been exceptionally dry.

Further experiments were made in 1907 at Kotu, and several samples of the fibre examined at the Imperial Institute were found to be of good serviceable quality. The yield per acre, however, was too small and the cost of production too great for the crop to prove remunerative.

Sierra Leone.—Considerable attention has been devoted to jute growing in Sierra Leone, and much interest has been taken in it by the Government of that Colony. A specimen of fibre, probably derived from *Corchorus capsularis,* grown in the Ronietta district, was examined at the Imperial Institute in 1905, and was found to resemble Indian jute in both chemical and mechanical properties. A specimen of the fibre of *C. capsularis* grown at Kangahun was composed of fine, soft, silky, lustrous fibre, of good colour, but poor strength, and was valued at £22–

£23 per ton with medium qualities of jute at £22–£25 per ton. This fibre had been well cleaned, but had probably been over-retted and was therefore weak.

On the whole, the results obtained in Sierra Leone were not very successful; this was largely due to the ignorance of the natives with regard to the methods of cultivation, and partly to the fact that no manure was applied.

Southern Provinces, Nigeria.—An experimental trial was carried out at Old Calabar in 1896 on a somewhat unsuitable, light, sandy soil. The seed was sown rather late, and the dry season was well advanced before the plants were fully grown. On account of these unfavourable conditions, the crop matured early and, in consequence, the fibre was of short staple. In other respects, however, it was of satisfactory quality.

In 1907, a specimen of the fibre of *Corchorus olitorius*, grown on the Onitsha Plantation, was examined at the Imperial Institute, and was found to be of fair colour and lustre, but weak and rather harsh, and had probably been over-retted; it was regarded as worth £14 10*s*. per ton, when medium qualities of Calcutta jute were quoted at £14–£16 per ton.

Two samples of the product of *C. capsularis*, grown in the Western Province, were also received at the Imperial Institute in the same year. One of these samples, grown from a green-stemmed variety, was soft, lustrous, of good length and strength, and was considered to be equal to "good medium" Bengal jute and worth £15–£16 per ton, with "first marks" Calcutta jute at £14 per ton; this fibre would have been more valuable if about 6 inches of the rough root-end had been cut off as is done in Bengal. The other sample, from a green-stemmed variety, was of similar quality but darker colour, and was valued at £13–£14 per ton and said to be saleable in any quantity.

Northern Provinces, Nigeria.—Two samples of jute, grown in Northern Nigeria, one from imported seed and the other from local native seed, were examined at the Imperial Institute in 1907. The former consisted of soft, fine, greyish, fairly lustrous fibre, but had not been very well cleaned. The fibre was about 4 feet long, and was regarded as very suitable for spinning and worth £24 per ton, with medium qualities of Indian jute at £23–£25 per ton. The sample grown from native seed was harsher, more brittle and had not been well prepared; it was valued at £22 per ton.

A specimen of native jute cultivated by riverside villagers in the Borgu Province was also examined at the Imperial Institute. It consisted of nearly white, fairly well cleaned, rather harsh fibre, about 5 feet long, and on the whole of good quality, but rather harsh and weak.

Jute Substitutes

There are numerous plants of the natural orders, Malvaceæ and Tiliaceæ, which yield bast fibres similar to jute and capable of replacing it in manufactures. From a commercial standpoint, the two most important of such plants are *Abutilon Avicennæ* and *Hibiscus cannabinus* which yield the fibres known in the markets of the United Kingdom as "China jute" and "Bimlipatam jute" respectively. The methods of preparing these fibres are essentially the same as those employed in the case of jute. In the following pages, attention is given more particularly to the jute-like fibres of West Africa.

Abutilon spp.—*Abutilon Avicennæ*, the Indian mallow, a plant of the natural order Malvaceæ, is cultivated on an extensive scale in China, and the fibre, which is strong and lustrous, is exported under the name of "China jute." It is said to yield about one ton of fibre per acre. The plant has been introduced into the United States of America, and grows there luxuriantly; the seed is able to withstand the severity of the winter, and the plant is thus enabled to propagate itself continuously. *A. asiaticum* and *A. indicum* occur in India, and also in parts of West Africa, and yield fibres similar in character to that of China jute.

Hibiscus spp.—A large number of species of Hibiscus, also belonging to the Malvaceæ, yield jute-like fibres.

Hibiscus Abelmoschus.—This plant is cultivated throughout West Africa, and grows in most tropical countries. A sample of the fibre from India, examined at the Imperial Institute, was found to possess characters strongly resembling those of jute.

Hibiscus cannabinus.—This species is cultivated in India, chiefly in Madras, but also in Bombay, Bihar, and the United Provinces, and the fibre is known as "Ambari hemp" or "Deccan hemp." A considerable amount of fibre is produced in Madras and exported to the United Kingdom, where it is sold under the name of "Bimlipatam jute" and realises prices about equal to those of medium grades of jute. It has been estimated that the crop yields from two to three tons of fibre per acre. A study of *Hibiscus cannabinus* has been carried out by the Agricultural Department in India, and seed of the best races has been selected for multiplication, so that pure seed can now be supplied in large quantities to the growers. The fibre of this plant is somewhat coarser than true jute, but can be used for most purposes to which jute is ordinarily applied. *Hibiscus cannabinus* is also grown in West Africa and in many other tropical countries. It is an important fibre-plant of Nigeria.

Hibiscus esculentus.—This plant is the well-known "Okra," "Awkraw" or "Bhindi," which yields a mucilaginous seed-pod used in many parts of the world as a vegetable and appears to be grown in all parts of West Africa.

A sample of "Awkraw" fibre was forwarded to the Imperial Institute from Sierra Leone in 1905. The material was of a pale straw colour, fairly lustrous, but not well cleaned, somewhat harsher than jute, and about 3½ to 4 feet long. On chemical examination it was found that "Awkraw" fibre is of a somewhat different character from Indian jute, and is much more susceptible to the attack of alkali and on this account would probably be somewhat less durable. Commercial experts reported that this fibre could be spun with good results when mixed with jute, and if of somewhat greater strength would be worth from £18 to £20 per ton (with jute at from £16 to £25 per ton), and would no doubt find a ready sale.

A second sample of the fibre, described as "Okra" fibre, was sent from Sierra Leone for further investigation in 1906. This sample was obtained from the plants after the second series of fruits had been gathered, in order to test the value of the fibre prepared at this particular stage. The fibre was mostly from 2 feet to 2 feet 8 inches long, but some short strands about 18 inches in length were also present. In general the product resembled the previous sample of "Awkraw" fibre, but was softer, whiter, and more lustrous, though only about two-thirds the length. The strength was poor and uneven. Commercial experts, to whom the sample was submitted, described it as a brittle, jute-like fibre which, though of good colour, was mostly tender and weak. Its value was considered doubtful, but probably from £20 to £22 per ton. At the time of this valuation, jute prices were much above the average, and, under ordinary conditions, this sample would not have been worth more than about £15 per ton. As a sample of fibre prepared from the older plants was valued at £18 to £20 per ton when prices were normal, it appeared that in spite of the better appearance of the sample under consideration, its value would be less on account of its inferior length and poor strength. It is, however, unsafe to draw a general conclusion as to whether the period at which the sample was collected is the best until further experiments have been made.

Another specimen of "Okra" fibre received from Sierra Leone was well cleaned, soft, nearly white, lustrous, of fairly good strength, and about 5 feet long. The fibre compared favourably with the sample examined in 1905. The proportion of cellulose was lower, but the comparatively small losses sustained on hydrolysis showed that the fibre was likely to resist the action of water satisfactorily. This product was well grown and beautifully prepared; it was valued at £20 per ton (with "medium" jute at £15–£17 per ton), and was said to be readily saleable in large quantities. This sample of fibre was prepared from

" Okra " plants cut after the first crop of fruits had been gathered.

A sample of the fibre of *Hibiscus esculentus*, received at the Imperial Institute from the Southern Provinces, Nigeria, was of uneven quality. The best portion was almost white, lustrous, rather harsh and not very well cleaned and prepared ; the remainder was of darker colour and of irregular staple. The product was valued at £18 per ton (with " medium " jute at £23–£25). The harshness of the fibre suggested that it had been prepared from old plants, and it had evidently been insufficiently retted.

Hibiscus guineensis.—This species occurs in the Southern Provinces, Nigeria, and is known to the natives as " Ramo." A specimen of the fibre forwarded to the Imperial Institute from Olokomeji in 1907 consisted of well cleaned, nearly white fibre, of good lustre and fair strength, but was rather harsher than jute ; its length varied up to a maximum of 7 feet. The fibre would prove valuable as a jute substitute, and would be saleable in large quantities at £17 per ton (with " medium " jute at £15–£17 per ton).

Hibiscus lunariifolius.—It is stated that this plant, which is known in the Northern Provinces of Nigeria as " Ramma," is, with the exception of cotton, the only one systematically cultivated in that country as a source of fibre. An account of the cultivation has been given by Mr. Gerald C. Dudgeon on pp. 138–140 of the handbook of this series, entitled *The Agricultural and Forest Products of British West Africa*. Fibre was exported from the Northern Provinces in large quantities in 1908 and 1909, and it is believed that these consignments consisted mainly or entirely of the product of *H. lunariifolius*. The exports in 1908 amounted to the value of £1,382, and in 1909 to the quantity of 755,690 lb. of value £4,050. In the following year, the exportation of the fibre seems to have ceased and has not since been resumed.

A sample of " Ramma " fibre from the Northern Provinces, examined at the Imperial Institute, consisted of brownish-white fibre which was on the whole well prepared but insufficiently cleaned. The product possessed good lustre and strength, and varied in length from 3 to 7 feet. The fibre suffered comparatively small loss on hydrolysis, and would therefore resist the prolonged action of water. It was too harsh for use as a jute substitute, but was suitable for making strong and durable ropes. It was regarded by experts as worth about £12 per ton (with "common" jute at £11–£12 per ton).

Another sample of the fibre, examined at the Imperial Institute in 1910, was found to be superior to the earlier sample, being of better colour, less harsh, and about 8 feet long. It was regarded as worth £16–£17 per ton (with "first native marks" Calcutta jute at £14 7*s*. 6*d*. per ton), and such fibre would be readily saleable as a substitute for jute.

Hibiscus quinquelobus.—This plant is known in Sierra Leone as "Kowe" or "Corwey" in Mendi, and "Nassim" in Timani, and is sometimes referred to as "West African jute." Owing to the facility with which this fibre can be prepared, it has received special attention, and efforts have been made to encourage its production. Experiments on the cultivation of this species have been conducted at Mabang. A small trade in the fibre was developed during the years 1904–05.

The first sample of the fibre submitted to the Imperial Institute consisted of well cleaned bast ribbons of fair strength. The length of the fibre varied from 3 feet to 7 feet 9 inches, most of it being about 5 feet long. The fibre was of a pale buff colour, of fair lustre, fine, and fairly soft. From the results of chemical examination it was evident that "Corwey" fibre is of good quality and resembles jute in its chemical composition and behaviour. The commercial experts to whom the sample was referred classed the material as a strong, bast-like fibre of good colour, and worth £25 to £26 per ton (June, 1906).

A consignment of about one ton of "Kowe" fibre was forwarded to the Imperial Institute in April, 1907. The product consisted of brownish-white ribbons composed of interlacing fibres which were slightly lustrous, well cleaned, rather harsh, of fair but uneven strength, and of irregular length varying from 3 feet 6 inches to 6 feet. In chemical composition and behaviour the sample was very similar to the "Kowe" fibre examined previously. The loss on hydrolysis was unusually low and indicated that the fibre would prove durable. The product was sold at public auction in London, with the result that a portion of the material realised £18 per ton, whilst the remainder sold at £17 5*s*. per ton. The brokers who sold the consignment reported that £18 per ton was about the price, subject to market fluctuations, which might be expected for future lots of this fibre, for which it seemed possible that a demand might be created. It is probable that the fibre was purchased by rope-makers, as at that time Manila hemp was at an exceptionally high price.

The sale of another small consignment in 1909 was attended with considerable difficulty, and a much lower price was obtained. It appears that, although the fibre can be used for spinning in admixture with jute, spinners do not care to purchase it when they can obtain ample supplies of Indian jute at a reasonable price. Moreover, it fails to attract rope-makers when Manila hemp is cheap and plentiful. It therefore follows that, in these circumstances, the fibre is classed in the market as "nondescript" and has to be sold at a very low price to anyone who can find a use for it.

Hibiscus rostellatus.—This species, known in the Gambia as "Darwaso," yields a moderately lustrous, nearly white fibre of the nature of jute.

Hibiscus Sabdariffa.—This plant grows in Northern Nigeria and in the Northern Territories of the Gold Coast, and is known to the natives of the latter country as "Rama." It is also cultivated in many parts of India and occurs in the West Indies and in Florida. The fibre is fine, strong and silky, and from 6 to 7 feet long.

Hibiscus squamosus.—A specimen of the fibre of this species, received at the Imperial Institute from the Gold Coast, consisted of strong, lustrous fibre, and was regarded by commercial experts as similar to " Daisee " jute from Calcutta.

Hibiscus tiliaceus.—This species is known in the Gambia as " Bafoodo julo." It is widely distributed in tropical countries and yields a fibre of fair quality. A sample from the Gambia, examined at the Imperial Institute in 1907, was fairly lustrous, but rather harsh, and about 5 feet long. Commercial experts reported that it was not of good spinning quality.

Honckenya ficifolia.—This plant, of the natural order Tiliaceæ, grows abundantly in the swamps of the Sierra Leone Protectorate, and would yield a perpetual supply of stalks for retting if care were taken in cutting it. It is known by the various names of " Napunti " (Timani), " Potepo " (Mendi), and " Bolobolo " (Yoruba).

Attention was directed to the fibre of this plant as long ago as 1888, when a sample, accompanied by botanical specimens, was forwarded from Lagos through the Colonial Office to the Royal Botanic Gardens, Kew. The fibre was reported by commercial experts to belong to the jute class, to be superior to jute in strength, and to be readily saleable, and worth at that time £16 per ton (*Kew Bulletin*, 1889, 15).

The preparation of this fibre was investigated by Government agents in Sierra Leone, who reported that considerable difficulty was experienced in separating the outer bark from the inner fibrous layer, and that this was particularly marked in the case of the older plants. Experiments were made with a view to ascertain whether the fibre could be more successfully extracted from young plants, but the results were not very encouraging.

The first sample of fibre forwarded to the Imperial Institute from Sierra Leone consisted of uncombed bast ribbons, which varied in length from 4 to 10 feet, the greater part being from 6 to 10 feet long. The fibre was well cleaned and prepared, but was of poor strength, and varied in colour from white to brown. On chemical examination the material furnished results which show that the " Napunti " fibre closely resembles Indian jute in its chemical character, and is nearly as rich in cellulose as "extra fine" Indian jute (compare page 138). It suffers a comparatively small loss on hydrolysis, and should consequently prove very resistant to the prolonged action of water. The product was described by experts as a jute-like fibre of mixed colour, and of value about £20 per ton (June, 1906).

A sample of "Napunti" fibre collected from young plants of the first year's growth, before they had flowered, consisted of soft, fine, greyish fibre of rather poor lustre; it had been well cleaned, but probably over-retted as its strength was very poor. It was from 3 feet to 3 feet 6 inches in length, and was regarded as worth about £20 per ton (with "medium" jute at £22–£25 per ton and "common" jute at £18 10*s*.—£20 per ton).

Two other samples, collected from old plants after flowering, were of little value, as they consisted of ribbons and tended to split up into short pieces on combing.

In connection with another sample of "Napunti" fibre, it was stated that the material represented the only form in which the natives could prepare this fibre, and it was consequently desired to ascertain whether it would have any commercial value. The sample consisted of a large bale of coarse, brown, fibrous bast ribbons, which were woody and gummy. The length of the ribbons was from 3 to 4 feet. The fibre in this form appeared to be only suitable for paper-making, but owing to its bulky nature, it seemed doubtful whether the exportation of such material would be remunerative in view of the cost of transport. A sample of the ribbons was submitted to a paper expert for an opinion regarding the suitability of the material for paper-making. He reported that it could be used for the manufacture of paper, but that he could not recommend bringing the raw material to England. It would be better, he thought, to consider the advisability of treating the material before shipment and reducing it to a condition of unbleached "half-stuff," leaving the paper-maker to bleach it as required. In the expert's opinion the unbleached "half-stuff" would probably fetch from £7 to £8 per ton if sold in sufficient quantity and if of uniform quality. Special experiments, however, proved that the "Napunti" ribbons as received yielded 47·3 per cent. of air-dry "half-stuff" (containing 8 per cent. of moisture), which is approximately equal to the amount furnished by esparto grass (page 219). Consequently over two tons of ribbons would be required to furnish one ton of "half-stuff." In view of these results it was considered extremely doubtful whether the course suggested by the expert would be remunerative. The cost of preparing the crude ribbons was given as about ½*d*. per lb. (£4 13*s*. 4*d*. per ton), and as the material yields less than half its weight of "half-stuff," valued at £7 to £8 per ton, there would be no margin for expenses, freight and profit. It is therefore evident that, unless the cost of production of the "Napunti" ribbons could be greatly reduced, there is not much chance of the fibre being utilised for paper-making.

Sida spp. (natural order, Malvaceæ).—*S. carpinifolia*, *S. rhombifolia* and *S. urens* occur in West Africa and yield useful fibres of the nature of jute. Samples of the fibre of *S. carpinifolia* from India, and of *S. rhombifolia* from India and Nyasaland, examined at the Imperial Institute, were found to be of useful quality and to resemble jute very closely in chemical composition and behaviour. Small consignments of *S. rhombifolia* fibre received from India in 1912 and 1913 were fine, soft, very lustrous, and of excellent quality, and it was considered that, if produced in commercial quantities, such fibre would realise a price about 20 per cent. in advance of that of "first marks" Calcutta jute. Unfortunately, the plant gives a somewhat smaller yield per acre than jute, and the fibre is more troublesome to prepare, owing to the interior of the stem being soft instead of hard and woody.

Triumfetta spp. (natural order, Tiliaceæ).—*T. cordifolia* and *T. rhomboidea* are both found in West Africa. A specimen of the fibre of *T. cordifolia* var. *Hollandii* from the Gold Coast, examined at the Imperial

Institute, consisted of soft, lustrous fibre, of pale buff colour and fine and even diameter; it was of good strength and 5 feet long. The fibre was of excellent quality, and was regarded as worth £35 per ton (with finest Bengal jute at £35–£40 per ton).

Samples of the fibre of *T. rhomboidea* from Nyasaland have also been examined at the Imperial Institute. The fibre was found to be of useful quality and suitable for employment as a substitute for medium grades of jute.

Urena spp. (natural order, Malvaceæ).—*Urena lobata* occurs in India, the United States, South America, Africa, and other countries. The fibre would probably be a good jute substitute. The plant is known in West Africa as "Na fen fe" (Timani), "Subwe" (Mendi), "Ake-iri" (Yoruba). It occurs everywhere along the West African coast, but is extremely variable in the form of its leaves. Good specimens of fibre have been prepared in Sierra Leone, but the plant growing there does not form long, straight stems, and the fibre is therefore rather short.

Samples of *Urena lobata* fibre from India have been examined at the Imperial Institute, and found to be fine, soft, lustrous, and of excellent spinning quality. The fibre was very similar to jute, and it was thought that, if produced in commercial quantities, it would realise prices a little in advance of "first marks" Calcutta jute. It is stated that in India by ratooning the plants a second year's crop can be obtained of equal value to that of the first year.

The product of *Urena lobata* is known in Brazil as "Aramina" fibre. The coffee trade of Brazil demands a supply of about 4 million bags per annum, and large quantities of jute yarn are imported from Dundee for their manufacture. The expansion of the coffee industry caused a search to be made for a Brazilian plant yielding a fibre suitable for the purpose, and this led to the discovery of "Aramina." A Company is now in existence at São Paulo, which was formed in 1905, to promote the cultivation of this plant, and to manufacture textiles and cordage from "Aramina" fibre and jute. A large factory has been established capable of producing 6,000 coffee bags per day. Samples of this Brazilian fibre have been examined at the Imperial Institute, and the results have been published in the *Bulletin of the Imperial Institute*, 1903, I, 24–25.

Urena lobata is also being grown for its fibre in Madagascar and in Cuba.

A sample of the fibre of *Urena lobata*, received at the Imperial Institute from the Gambia, was soft, of a greenish-grey colour, well cleaned and prepared, fine, lustrous, of good strength and about 3 feet long. In chemical composition and behaviour, the fibre was superior to a specimen of " medium quality " Indian jute with which it was compared. It was only half the usual length of jute, but would nevertheless be readily saleable as a jute substitute at £17 per ton (with " medium " jute at £15–£17 per ton).

In Northern Nigeria, *U. sinuata* is grown by the road-sides, and is said to be cultivated to some extent in Bida (Nupe Province) for the manufacture of ropes, where it is known by the name of " Rama."

CHAPTER VII

CORDAGE FIBRES

For many centuries, hemp (the fibre of *Cannabis sativa*) has been employed on an extensive scale for the manufacture of cordage (see Chapter V). As the cultivation of this fibre in Europe gradually declined to some extent on account of the increased cost of production, due especially to insufficiency of labour, attention was directed to certain tropical products which are suitable as substitutes. The most important of these is Manila hemp which serves as the best material for the manufacture of marine cordage. Other fibres, which have come into prominence and find a ready market for the rope and twine industry, are Sisal hemp, Mauritius hemp and New Zealand hemp.

MANILA HEMP

Manila hemp, or Abaca fibre, is produced almost exclusively in the Philippine Islands. From time to time, attempts have been made to introduce it into other countries, but usually with little or no success. In the year 1822, an effort was made to grow the plant in Bengal, and in 1859 it was introduced into Madras, but in neither case was a satisfactory result obtained. In 1873, an experimental trial was made in the Andaman Islands, and the plant proved to be well adapted to this locality. The cultivation of the plant and the preparation of its fibre in the Andaman Islands, however, have never become an important industry, and but little attention is paid to it. Attempts have also been made to introduce the plant into British North Borneo and the West Indies. During recent years, some success has been obtained with Manila hemp in Java. The fibre produced in this island is not of so fine a quality as that of the higher grades produced in the Philippines but is nevertheless quite suitable for the market. It is considered that the cultivation of this product might perhaps have a good future in Java as a native industry.

The Manila Hemp Plant

Manila hemp is derived from the sheathing leaf-stalks of *Musa textilis*, a plant of the banana or plantain family. The plant has a branching underground stem or rhizome which bears numerous small roots. From time to time, this rhizome throws up erect stems so that an old plant may bear from ten to twenty-five shoots of various ages growing in a cluster. The apparent aerial stem is composed of from sixteen to twenty-five broad, overlapping leaf-bases (or, rather, sheathing petioles) which grow up, one inside another, until they form a kind of trunk, 12 to 16 inches in diameter. The real stem arises through the middle of this structure and is usually not more than about 3 inches thick. When the formation of the sheaths is completed, the flower-bud develops and puts forth a thick axis or spike on which the flowers are produced in clusters; the clusters nearer the base bear pistillate or female flowers, whilst those nearer the summit bear the staminate or male flowers. The fruit is smaller than that of most bananas; it is hard and green, unfit for food, and contains numerous large, black seeds. In general appearance, the plant resembles the ordinary fruiting banana, but the leaves are paler in colour, narrower and more pointed, whilst the stems are of a purplish-red colour with broad, green streaks.

Cultivation

Climate.—Since the Manila hemp plant bears enormous leaves and only very short roots, it requires considerable humidity both of the atmosphere and of the soil, and is therefore only able to thrive in countries which possess a somewhat heavy rainfall, more or less evenly distributed throughout the year. A drought of two or three weeks greatly hinders growth, whilst a prolonged drought is usually fatal. The occurrence of rain every two or three days is beneficial, but a continuous wet season is unfavourable. The plant demands a warm climate, and probably would not grow in a satisfactory manner in regions with a average temperature of less than 72° F. It grows most rapidly and luxuriantly in the open plains, provided that there is always a sufficiency of moisture, but it can also be cultivated in districts which possess a moderately dry season, if planted in sheltered situations. High winds are exceedingly injurious, and in windy places the plantation must therefore be protected by a belt of large trees. The production of Manila hemp is sometimes carried on in the Philippines at altitudes of as much as 3,000 feet above the sea, but the yields are not so high as those obtained in lower situations, and, in general, the temperature is too low for perfect development at elevations of more than 1,000 to 1,600 feet.

Soil.—The Manila hemp plant requires a loose, moist soil, rich in humus, and well drained ; it will not thrive on swampy land. The presence of a moderate amount of potassium is necessary, and potash manures should therefore be added if the soil is deficient in this constituent. Plant ashes are commonly employed for this purpose. It is probable that the presence of large quantities of lime is also desirable. The configuration of the land is of some importance, level lands being usually more favourable than the hillsides, except in districts with a very heavy rainfall.

Propagation.—The plant is usually propagated by means either of root-cuttings or, most commonly, of the suckers which arise at the base of the parent plant, but sometimes it is grown from seed. In the latter case, the seeds must be collected from fruits which have not become over-ripe. They should be thoroughly washed and afterwards soaked for several hours and planted, 6 to 8 inches apart, at a depth of about an inch. The seedlings may be transplanted after ten or twelve months.

Planting.—New plantations are usually established on freshly cleared forest land. The young plants, whether grown from suckers, rhizomes or seed, are planted about 8 to 10 feet apart in straight rows, this arrangement giving about 700 to 450 plants per acre If possible, the ground should be well ploughed; this, of course, cannot be done on land which has only just been cleared but, in such cases, the soil must be well broken up round each plant. The plantation requires very little attention subsequently, but the larger weeds are usually cut down about twice a year. In some cases, the growth of weeds is kept down by planting camotes (sweet potatoes) or leguminous plants, such as cowpeas and velvet beans, between the rows, but this should not be done until the Manila hemp plants have attained a height of at least 12 inches.

Harvesting and Preparation of the Fibre

The fibre reaches its maximum tensile strength shortly before the shoot flowers. At this stage, the stalk is cut in a slanting direction a few inches from the ground, and the leaf-sheaths are afterwards stripped off. As a rule, cutting should not be commenced until the plant is from two to three years old. Subsequent cuttings can be made every six or eight months. The coarser and stronger fibre is located in the outer part of the sheath, whilst the fibre of the inner part is comparatively soft and weak. For this reason, the outer layer is separated from the inner portion, and the latter is usually thrown away. The outer part is then cut into strips, about 2 to 3 inches in width, and each strip, while still fresh and succulent, is drawn between the edge of a blunt knife or "bolo" and a hard, smooth wooden block attached to a light frame constructed of rattan canes. By repeated scraping, all the soft, pulpy, cellular tissue is removed, and the clean fibre remains in the hands of the operator. The product is then hung on bamboo poles or wire lines and allowed to dry in the sun as rapidly as possible, and is afterwards tied up in bundles and finally graded and baled for export. It is of great importance that the fibre should be thoroughly dry, as otherwise it is liable to become weak and discoloured. The bales weigh about 275 lb. each.

Machines have now been introduced into the Philippines for extracting the fibre, and it is probable that before long they will be adopted in all the larger plantations, and the old methods of cleaning by hand will gradually be superseded.

During the usual process of separating the strips, part of the fibre is left attached to the inner layer of the sheath, and in drawing the strips under the knife a further quantity is lost. It is estimated that the amount of waste created in these two operations is not less than 30 per cent. of the total fibre.

Yield

The freshly cut stalks weigh from 90 to 220 lb. each, and give from one to five lb. of fibre. According to another estimate, the fresh stalks yield from 1½ to 2½ per cent. of dry fibre. The yield per acre depends on various factors, such as the method of cultivation, the particular variety grown and the conditions of soil and climate of the locality. The annual yield varies from 3 cwts. to 1 ton per acre, ½ ton per acre being usually regarded as very satisfactory.

Properties, Structure and Uses of the Fibre

The Manila hemp of commerce is composed of strands from 6 to 10 feet long, which are generally flattened and appear more or less oval in cross-section. The colour varies from pale straw to brown, but when the product has been carefully extracted and dried it is nearly white and highly lustrous. The fibre is very strong and tenacious, and is so light as to be able to float on water.

The strands are composed of aggregations of small, ultimate fibres which are from 0·08 to 0·12 inch long, and have a diameter of 0·0005 to 0·0017 inch with an average of about 0·0012 inch. The walls of these ultimate fibres are of fairly uniform thickness and enclose a large central cavity. The fibres taper gradually at the ends and terminate either in a sharp or slightly rounded point.

Air-dried Manila hemp usually contains from 10 to 12 per cent. of moisture, but the fibre is very hygroscopic, and, if exposed to an atmosphere saturated with water-vapour, it is capable of holding as much as 50 per cent. The product consists of a somewhat lignified form of cellulose. The examination of a specimen of commercial Manila hemp of good quality at the Imperial Institute gave the following percentage results: Moisture, 10·2; ash, 1·1; loss on α-hydrolysis, 11·2; loss on β-hydrolysis, 17·8; loss on acid purification, 1·6 per cent.; cellulose, 78·6 per cent.

As has already been stated, the principal use to which Manila hemp is applied is for the manufacture of ships' ropes and cables, for which purpose it is particularly adapted by its great tensile strength and its lightness. In the Philippines, some of the finer qualities are woven into muslins and other fabrics for the local market, and a small quantity of the fibre is employed in upholstery, packing, and brush-making. The waste material obtained in the process of preparing the fibre can be utilised for paper-making and yields paper of excellent quality.

Grading and Commercial Value

In grading Manila hemp, attention is directed chiefly to the softness, colour and strength of the fibre. These characters are dependent on a number of factors, including the variety cultivated, the conditions of soil and climate under which the crop is grown, and the methods employed in extracting and preparing the fibre. The quality also varies considerably with the size of the stalk, large stalks yielding darker, coarser and stronger fibre than smaller ones. The position of the sheath in the stalk also has a great influence on the nature of the product; the fibre becomes softer, whiter and weaker from the outside sheaths towards the centre, the innermost sheaths yielding the softest, whitest and weakest.

In order to regulate the industry and to effect an improvement in the quality of the fibre produced, a compulsory grading system was introduced by the Philippine Government in 1914, and standard grades were established. The regulations came into force on the 1st January, 1915.

Manila hemp (well cleaned fibre) is graded into "extra prime," "prime," "superior current," "good current," "midway," "current," "seconds," "brown," "damaged," "strings," and "tow."

Manila hemp strips (partially cleaned fibre) are graded into "fair," "medium," "coarse," and "coarse brown."

As an indication of the relative values of the different grades, a list of prices quoted in the London market in June, 1915, is given below.

Grade.	*Price per ton.* £	*Grade.*	*Price per ton.* £
Extra Prime	56–58	Seconds	38–39
Prime	52–54	Brown	36–38
Superior Current	50–52	Fair	37–38
Good Current	48–50	Medium	32–33
Midway	44–46	Coarse	28–29
Current	41–42	Coarse Brown	27–28

Production and Export

The growth of the Manila hemp industry of the Philippines is shown by the following list of exports.

Total Exports of Manila Hemp

Year.	Tons.	Year.	Tons.
1818	41	1900	89,438
1825	276	1904	121,637
1840	8,502	1909	165,299
1850	8,561	1910	160,595
1860	30,388	1911	146,208
1870	31,426	1912	172,347
1880	50,482	1913	117,904
1890	67,864	1914	114,554

The chief importing countries are the United States and the United Kingdom. The quantities and values of the exports to the United Kingdom during 1909–1915 were as follows:

IMPORTS INTO THE UNITED KINGDOM *

Year.	Quantity. Tons.	Value. £
1909	58,583	1,374,896
1910	64,106	1,520,199
1911	75,449	1,647,542
1912	83,313	1,990,481
1913	64,579	2,000,450
1914	54,206	1,396,593
1915	57,783	1,760,471

The great demand for Manila hemp has led the growers to increase the production at the expense of quality with the result that comparatively small quantities of the better grades are now produced, the great bulk of the exports consisting of the poorer grades. In consequence of this large output of the inferior qualities, prices fell very considerably after 1907. The following are the London market quotations in January of each of the years 1906–1916:

Date.	Fair Current † Per ton. £	s.	Good Current. Per ton. £	s.
1906	40	0	48	5
1907	42	0	53	0
1908	29	0	38	10
1909	23	10	33	15
1910	26	5	32	15
1911	19	0	34	10
1912	21	10	34	10
1913	34	0	69	0
1914	27	15	57	0
1915	28	10	43	10
1916	56	10	63	10

* These figures include small quantities of "Maguey" fibre (see p. 167).

† This grade was about equal or slightly superior to the "fair" quality of the new grading system.

Banana and Plantain Fibres

Besides the Manila hemp plant, there are several other species of *Musa* which bear fibrous leaf-sheaths. Among these the most common is the ordinary fruiting banana. The fibre extracted from this plant is, however, generally much weaker than Manila hemp, and would be of comparatively little value for cordage manufacture. There are enormous quantities of banana stems cut down after the fruit harvest and thrown away, which presumably might be employed for the production of fibre. It must be borne in mind, however, that when the market values of other cordage fibres, such as Manila and Sisal hemps, are low, the fibre of the fruiting banana would only realise very low prices and would not be profitable to extract. It has been suggested that the banana leaf-sheaths might well be employed on the spot for conversion into pulp for paper-making. The product might either be exported as pulp or manufactured into paper. The erection of pulp or paper mills involves a large initial outlay, but in the case of a country with a large banana industry, it is possible that it might yield a satisfactory return. On the other hand, it has been pointed out that for the manufacture of one ton of paper, no less than 132 tons of the raw material would have to be handled, and that the cost of collecting, cleaning, drying and crushing the material, and converting it into pulp, would be very considerable. Moreover, the class of paper produced would not be of very good quality.

Experiments made in Jamaica in 1884 showed that a banana stem after fruiting, which weighed 108 lb., yielded 25 oz. of clean fibre or about 1·44 per cent. of its gross weight. The stems of the plantain, which is used as a vegetable, gave yields amounting to about 2 per cent. of a fibre which was superior to the banana fibre, being whiter and finer and more like Manila hemp.

In the East Africa Protectorate, there is a banana plant (*Musa Livingstoniana*) which grows wild in several districts, and yields a fibre of good quality.

Samples of this fibre have been examined at the Imperial Institute, and are described in *Selected Reports from the Scientific and Technical Department, I.—Fibres* (Cd. 4,588). They were regarded by commercial experts as comparable with the best fibres used for rope-making and similar to the superior grades of Manila hemp, and it was stated that such fibre would be readily saleable in the London market.

The fibres of two other species growing in East Africa, viz. *M. Ensete* and *M. ulugurensis*, have also been examined at the Imperial Institute. These fibres are prepared by the natives in a very primitive manner, but samples from each species which were forwarded to Germany in 1903 were reported by experts to be of very good quality, though inferior to true Manila hemp. The plants do not produce suckers, and therefore can only be propagated from the seeds, which in both cases germinate fairly easily. The yield of fibre from *Musa ulugurensis* is small in comparison with that from *Musa textilis*, the Manila hemp plant, but it is possible that this disadvantage may be compensated by the more rapid growth of the former plant and by cheaper labour and improved methods of fibre extraction.

The examination of these fibres at the Imperial Institute showed that both are of a useful character, that of *M. Ensete* being decidedly superior to that of *M. ulugurensis*. Both products were regarded by commercial experts as of very promising quality and equal in value to high-grade Manila hemp.

Banana Fibre in West Africa.—Bananas and plantains are cultivated in all parts of West Africa. Specimens of fibre prepared from these plants in Sierra Leone, the Gold Coast, and Southern Nigeria have been investigated at the Imperial Institute.

Three samples forwarded from Sierra Leone in 1902 were of inferior quality, and although this was largely due to defective preparation, it was still considered unlikely that these fibres would be of value for any but local uses.

A specimen received from Southern Nigeria in 1906 under the name of "Ndehe Ukom" was white, very lustrous, of fair but uneven strength, but only about 2 feet long.

A specimen of well cleaned plantain fibre, which was brownish-white and of good lustre, was forwarded from the Gold Coast in 1907. The product was of fair but very irregular strength and about 4 feet long. It was superior to other specimens of plantain fibre which had been examined at the Imperial Institute, and was regarded by commercial experts as worth £40 per ton (with "good" Manila hemp at £38 to £42 per ton). A sample of banana fibre, which was forwarded at the same time, consisted of well cleaned, brownish-white fibre, of good lustre, but uneven diameter and very irregular strength. The product was about 4 feet long, and very similar to the preceding sample. It was valued at £36 per ton (with "fair" Manila hemp at £35 to £36 per ton).

SISAL HEMP

Sisal hemp, so-called from the name of a port in Yucatan, Mexico, whence it was first exported, is a valuable cordage fibre, derived from the leaves of *Agave sisalana* and certain other species of Agave. These plants are members of the natural order Amaryllidaceæ; they are commonly, but erroneously, spoken of as "aloes" and must not be confounded with the true aloe which is of widely different character. The Sisal plant has a short trunk bearing a number of thick, fleshy leaves, which range from three to six feet in length and from about four to six inches in width. At a certain age, which varies in different countries and seems to depend largely on the climatic conditions, it throws up a "pole" or flowering stem twenty to thirty feet high. The flowers are produced in dense clusters at the ends of short lateral branches, and after they have begun to wither buds arise in the axils of the flower-stalks. From these buds arise small plants, known as "bulbils," which grow to the length of a few inches, and then fall to the ground and, under suitable conditions, take root. After the production of the bulbils, the whole plant withers and dies.

The Agaves are indigenous to South America and the southern parts of North America, especially Mexico. They have been introduced into many other countries, including Florida, the Bahamas and other parts of the West Indies, British Honduras, South Africa, East Africa, West Africa, Madagascar, Mauritius, India, Indo-China, the Dutch East Indies, the Philippine Islands, the tropical parts of Australia, Papua, Fiji, and Hawaii.

There are a great many different kinds of agave in existence and so much confusion has arisen with regard to their nomenclature that it is often extremely difficult to establish the identity of plants yielding commercial varieties of fibre. Comparatively recently, however, Professor Lyster Dewey, of the United States Department of Agriculture, has stated that there are only three species which are concerned with the question of the commercial production of Sisal hemp. These are as follows: (1) *Agave fourcroydes*, the Yucatan Sisal plant, which furnishes over 90 per cent. of the world's supply; the leaves of this species bear marginal spines. It was formerly known as *A. rigida* var. *elongata*, and occurs in Mexico, Cuba, and South America, and has been introduced into East Africa. (2) *Agave sisalana*. This species is grown for local use by the natives of Central America and Southern Mexico, but is not exported from Yucatan to any great extent. It is cultivated commercially in the Bahamas, West Indies, East Africa, India, Indo-China, and to a small extent in Java. (3) *Agave Cantala*. This is the "Maguey" plant of the Philippine Islands, and is grown in limited quantities in Java and India.

Production

The first attempts to introduce Sisal hemp into commerce were made in Mexico in 1839. The fibre was cleaned in a primitive manner, and was afterwards packed in loose bales and sent to New York, where it found a market but was not very remunerative. The methods of preparation were so slow and tedious that, even with the cheap labour of that time, the cost of production was discouraging. The State Government, recognising the need for a suitable machine to extract the fibre, offered a prize to the inventor of an apparatus capable of producing a certain quantity per hour. This offer resulted in the invention of the "raspador" machine (see page 175) by a Franciscan friar and led to a gradual expansion of the industry. The following figures illustrate the development since 1880. In that year the exports of "henequen" (as the product is termed in Mexico) amounted to about 18,820 tons; in 1885, 44,580 tons; in 1890, 46,680 tons; in 1895, 63,900 tons; in 1900, 83,270 tons; in 1905, 99,500 tons. Since 1905, the annual export has been, on the average, rather over 100,000 tons per annum. The value of the fibre exported from Mexico in the year 1913 amounted to over £3,000,000. A large proportion of the fibre (over 90 per cent.) is exported to the United States, where it is employed for the manufacture of binder twine used in harvesting the immense crops of the Western States. The rest of the exports are consigned to European countries.

Imports of Sisal Hemp into the United States

From	1911.	1912.	1913.	1914.	1915.
	Tons.	*Tons.*	*Tons.*	*Tons.*	*Tons.*
Mexico	111,405	103,683	136,559	195,086	175,884
Germany*	2,285	6,731	13,295	11,917	2,144
United Kingdom	700	789	675	625	2,327
British West Indies †	2,987	3,195	3,023	3,659	2,935
Cuba	—	—	44	1	1
British India	49	16	—	14	4
Dutch East Indies	87	—	—	3,325	2,150
Philippine Islands	32	—	—	—	—
East Africa Protectorate	148	—	—	10	—
Other countries	34	53	273	910	319
Total quantity	117,727	114,467	153,869	215,547	185,764
Total value	£2,519,284	£2,472,259	£3,709,129	£5,387,652	£4,285,906

* Probably mostly or entirely derived from German East Africa.
† Almost entirely from the Bahamas.

The Sisal hemp or "Pita" plant has long been acclimatised in the Bahamas, but was not seriously regarded as worthy of systematic cultivation until 1888 when the Governor of the Islands took steps to encourage the establishment of a local fibre industry. During the next few years, several large undertakings purchased extensive tracts of land and planted them with the Sisal agave. The rapid growth of the industry is shown by the following data of the quantities and value of the fibre exported in certain years:

Year.	Quantity. Tons.	Value. £	Year.	Quantity. Tons.	Value. £
1891	9	149	1903	1,439	38,805
1892	30	692	1906	1,726	40,140
1893	52	1,200	1909	2,610	48,805
1894	79	1,728	1911	2,979	44,855
1895	242	3,987	1912	3,600	66,427
1897	402	4,522	1913	3,236	69,950
1899	607	16,942	1914	2,502	46,685

The whole of the fibre exported from the Bahamas enters the United States.

The production of Sisal hemp in India has not assumed important dimensions, although it has frequently been made a subject of commercial enterprise. The cultivation of agaves has been carried on for several years on a plantation in Assam, but the results have not been such as to warrant any great extension of the industry. In the Coimbatore District, Madras, the fibre has been extracted on a commercial scale from plants growing beside the railway. Sisal plantations have been established by several European undertakings in Madras, but the crop is not attractive to the ryots. In the Central Provinces, *Agave Cantala* is grown to some extent as a hedge-plant, but comparatively little fibre is extracted. Agaves also occur in Burma, but are not systematically grown for fibre. The actual amounts of Sisal hemp exported from India are not known, as the official returns do not class this fibre separately but include it with Sunn or Bombay hemp (*Crotalaria juncea*) under the general heading of "hemp."

In the Philippine Islands the production of Sisal hemp or "Maguey" fibre constitutes a comparatively small but gradually increasing industry. The exports, which are consigned chiefly to the United Kingdom and the Continent of Europe, amounted to 875 tons in 1901; 1878 tons in 1905, and 4,484 tons in 1911.

In the three following years the quantity and value of the exports were as follows:

	1912.	1913.	1914.
Quantity, *tons*	7,038	6,958	5,440
Value, £ .	114,436	123,115	86,887

The Sisal hemp plant was introduced into East Africa in 1893. In that year the German East Africa Company ordered 1,000 plants from Florida, but only 62 of them survived the journey. These were carefully tended in a plantation at Kikogwe, and new plants were propagated from them, so that in 1898 the number had increased to 63,000. In 1899, machinery was introduced for extracting the fibre. By the beginning of 1900 there were as many as 150,000 plants established, of which 4,000 were more than three years old and were ready for cutting. The first shipment of fibre was made in 1900, and consisted of 7½ tons, of value £155. From this time forward the industry progressed at a remarkable rate, as is shown by the accompanying table, which records the quantity and value of the exports of the fibre from German East Africa during the years 1905–1913.

—	1905.	1906.	1907.	1908.	1909.	1910.	1911.	1912.	1913.
Quantity (metric tons) . . .	1,397	1,854	2,830	3,897	5,284	7,228	11,213	17,079	20,835
Approximate value (£) . . .	53,000	68,000	108,000	143,000	116,000	150,000	226,000	367,000	535,000

In British East Africa, the cultivation was started in 1903, experiments being made first in the Nairobi District, and a little later in other districts. The plants have reached maturity on many of the plantations and the extraction of the fibre has been commenced. On a plantation of about 1,000 acres at Punda Milia in the Fort Hall District, a factory has been erected which is provided with machinery for extracting and baling the fibre. Excellent results have been obtained and consignments placed on the market have been reported to be of high grade, and have realised maximum prices. Machinery has also been installed at Nyali on the mainland, opposite the island of Mombasa, and at other places in the Protectorate. The industry has gradually extended, and in 1913 about 7,000 acres were under cultivation. Sisal plants grown at the coast yield a higher percentage of fibre than those grown in the highlands and also furnish a finer fibre, but in the highlands a larger yield per acre is obtained and the cost of labour is less. The prospects of the industry appear very promising both at the coast and in the highlands.

The exports of Sisal hemp from British East Africa in the year 1913–14 were as follows:

To	Quantity. *Cwts.*	Value. £
United Kingdom .	16,573	9,670
Germany . . .	811	473
United States . .	4,083	2,382
Total . .	21,467	12,525

In 1914–15, the total exports amounted to 33,621 cwts. of value £36,059.

The cultivation of Sisal hemp has been undertaken recently in the Nyasaland Protectorate, and, in 1914, about 400 acres in the Blantyre district were devoted to this crop. The cultivation of experimental plots at various altitudes in Nyasaland has shown that the higher localities are too cold and that the most satisfactory results are obtained below 2,500 feet.

Efforts are being made to establish a Sisal hemp industry in Papua, and in 1914 the area under cultivation amounted to 3,110 acres. During the year 1913–14, 142 tons were exported, of the value of £3,633.

Experiments in Sisal hemp growing were commenced in Fiji in 1907, and satisfactory results were obtained at the Nasinu and Lautoka Experiment Stations, situated respectively in the wet and dry regions of the island of Vitilevu, but the dry zone was found to be best adapted to the crop. Efforts are being made to encourage planters to take up the cultivation.

Sisal hemp is also being grown in comparatively small quantities in Mauritius, Jamaica and certain other islands of the West Indies, and in Queensland and the Northern Territory, Australia. Experiments have been made in Uganda, Rhodesia, and various other parts of the British Empire.

CULTIVATION

Climate and Soil.—The Sisal plant requires a tropical climate with moderate atmospheric humidity. It is very hardy, but is liable to be injured by excessive rain.

It is usually stated that the plant flourishes on rough, dry, stony or rocky soils which are unsuitable for other crops, but there is little doubt that good soils are not unfavourable. On poor soils, the plants are of somewhat inferior appearance but yield leaves containing a large proportion of fibre whilst, on rich soils, longer leaves are produced which furnish comparatively less fibre. It is probable, however, that in the latter case the greater length of the leaf more than compensates for the lower percentage of fibre. In general, it may be stated that the most suitable soil is a dry, permeable, sandy loam, containing a certain amount of lime. Good drainage is of great importance as the roots of the plants are sensitive to moisture and are liable to be seriously injured by standing water.

Preparation of the Land.—The land selected for a plantation should be fairly hilly in order to allow of easy drainage. Most writers agree that it is not necessary to break up the soil to any great extent,

From the Collections of the Imperial Institute

From the Collections of the Imperial Institute

SISAL HEMP PLANTS SHOWING LEAF-SCARS

Lautoka Experiment Station, Fiji

but the land must be cleared of trees and scrub, and stumps must be uprooted in order to render the surface even. On the other hand, it is stated that in German East Africa the best results are obtained on land which has been thoroughly cleaned and well hoed. In any case, it is essential that the undergrowth should be removed, as if the Sisal plants are shaded the fibre becomes weak and inferior. The land subsequently requires to be lightly hoed four or five times a year in order to keep it free from weeds.

Planting.—The Sisal plant comparatively rarely sets seed, and its propagation is therefore effected by means either of bulbils, which are produced in the manner already described (p. 166), or of suckers which arise from the rhizome. The bulbils are usually grown in nursery beds until about 8–12 inches high, and are then planted out. Suckers can be planted immediately after their removal from the parent plant. Planting is generally carried out during the rainy season, all fibrous roots and lower leaves having been first removed to facilitate new growth. The plants should be set in rows about 8 feet apart. The distance between consecutive plants in the row varies a good deal in practice, but probably 6 feet is the most satisfactory, this arrangement admitting about 900 plants per acre.

Harvesting and Yield.—The period which must elapse before harvesting can be begun varies in different countries, but, in general, after about from three to five years healthy plants will yield leaves ready for cutting. The cutting is effected by means of a special form of blade or sickle with a curved end. Each leaf is cut off close to the trunk, care being taken not to injure the younger leaves on the plant. The number of leaves which can be cut per annum varies greatly. It is estimated that in Mexico, each plant yields about twenty-five leaves a year, whilst in East Africa double that number are obtained. The average weight of the leaves in the latter country is about 2 lb., and the yield of dry fibre is approximately 3 per cent. Hence the yield of fibre per acre containing 900 mature plants should amount to about

2,700 lb., and a yield of at least a ton per acre may therefore be anticipated.

As the result of actual trials carried out at Punda Milia, it was found that 912 leaves, weighing 2,263 lb., or an average of 2·48 lb. per leaf, yielded 52½ lb. (2·32 per cent.) of dry, brushed fibre, equivalent to about 1 lb. of fibre from seventeen leaves. The plants from which these leaves were cut were spaced 8 feet × 8 feet, this arrangement giving 681 plants per acre. Taking 160 as the average number of leaves produced per plant during its life, the total yield per acre, when calculated by means of the above figures, is 6,240 lb., or a little less than 3 tons. As the plant lives at Punda Milia for about three years after the first leaves are ready for cutting, these observations are in agreement with the estimated yield of one ton per acre per annum given in the preceding paragraph.

Duration of Life of the Plant.—As has been already stated, the duration of life is determined by the production of the pole or inflorescence. In Mexico the plants are said to live for fifteen or sometimes even twenty-five years before poling, whilst in more tropical countries they live a much shorter period, the average length of life in German East Africa being only about six years. In general, the duration of the plant appears to be largely dependent on conditions of soil and climate. It has been asserted that the life may be prolonged by cutting out the pole as soon as it appears above the leaves, the plant being thus rendered available for fibre for nearly a year longer than it would be otherwise, but experiments which have been conducted in German East Africa do not support this view. The early poling of Sisal plants in East Africa has been much discussed and has been regarded by some planters as a great disadvantage. It appears, however, that the comparatively short life is due to the fact that there are two growing seasons in this country, and growth is checked twice a year, whereas in less tropical countries there is only one growing season per annum. Thus it is evident that the plant in East Africa lives through approximately the same number of growing seasons as it does in other countries, but only about half as many years. Moreover, the number of leaves produced per plant (on the average about 200) is roughly the same in each case, and hence the comparatively brief duration of life is rather an advantage than otherwise as the total crop of the plant is produced in a relatively shorter time.

Since the plants in a Sisal plantation do not all pole at the same time, the work can be carried on continuously by the intercalary method sometimes adopted in German East Africa. As the plant lives for only about six years, cutting can only be carried on for two or three years before it dies. New plants are therefore continually being inserted between the old ones, so that when one plant dies another is ready for cutting, and the work of the plantation can proceed without interruption. Some planters, however, do not approve of this method, but prefer to let all the plants in a plantation pole and die and then allow the land to lie fallow for a year or more before replanting.

Extraction and Preparation of the Fibre

The fibre is extracted from the leaves by a process of crushing and scraping or "scutching." The leaves should be treated as soon as possible after they have been cut, as otherwise the juices become dry and gummy, thus rendering extraction more difficult. They should be graded according to length before being scutched, and the fibre of the different lengths should be kept separate. The strands of fibre must be kept as parallel as possible, and not be allowed to become tangled. It must be borne in mind that good white fibre of uniform length and carefully cleaned and baled commands a much higher price than mixed fibre, ill-cleaned and badly baled.

Modern machinery for Sisal hemp extraction is based on the principle of the old "raspador" which was the earliest form of machine employed in Mexico. This machine consists of a wheel, like a four-foot pulley, with a 6 inch face, and with pieces of brass running across the face at intervals of about 12 inches. The wheel runs in a heavy wooden case and makes about 110 revolutions per minute. The leaf is inserted through a small hole in the case, and held firmly at one end by a strong clamp whilst the rest of the leaf is allowed to whip downwards as the wheel rotates. A heavy block, like the brake of a car-wheel, is brought by means of a lever on to the leaf and presses it against the revolving wheel. The leaf is thus crushed, and the pulp and epidermal tissue are scraped away by the brass strips and thrown into a pit under the wheel. The fibre is then withdrawn, and the leaf reversed in order that the other end may be cleaned in the same manner.

In East Africa large machines worked by power are generally employed which are capable of extracting from one to three tons of fibre per day. An illustrated account of these and other machines has been published in the *Bulletin of the Imperial Institute*, Vol. XIII (1915), pp. 440–442.

It is essential for the production of good, strong fibre that immediately after leaving the machine it should be well washed with clean water as otherwise both strength and colour are impaired. The factory must therefore be provided with an ample supply of water. Drying is effected by hanging the fibre on lines in the open air, care being taken that it does not become wetted by rain. After drying, the appearance of the product can be greatly improved by the use of a brushing machine to ensure the removal of any particles of dried pulpy matter which may still adhere to it.

Cost of Production

The cultivation and extraction of Sisal hemp on a remunerative scale require a large amount of capital, as at least 500 acres must be planted to warrant the erection of a factory and the installation of the necessary machinery. The crop is therefore unsuitable for individual planters, unless possessed of ample means, but it can be grown with considerable profit by a number of planters working in co-operation.

The cost of cultivating Sisal hemp and preparing it for the market varies greatly in different countries, and depends on the climate, soil, labour supply and other local conditions. The following results, based on actual experience at Punda Milia in the East Africa Protectorate, are of interest in this connection. The establishment of a plantation of 1,000 acres requires a capital of £4,000. The cost of machinery required to prepare the fibre from the leaves produced on a plantation of this size is £5,000. A return cannot be expected until four years after the plantation has been established. As already stated, one ton of dry fibre per acre per annum may be anticipated for three years from the date of the first cutting. The cost of producing a ton of dry fibre is about £12, including £1 per ton for transport to the railway.

It is estimated that in German East Africa the net profit varies between 15 and 30 per cent., depending on the current price of the fibre. The crop possesses several advantages, among which may be mentioned that it is almost immune from the attack of insects and practically free from disease, and that the manufacture of the fibre can be carried on more or less continuously throughout the year.

Characters and Properties of Sisal Hemp

Sisal hemp consists of strands or filaments from 3 to 5 feet long, of a nearly white or pale yellowish colour. It is very strong but a little harder and less flexible than Manila hemp. The fibre from different sources varies a good deal in diameter. The strands are composed of a mass of ultimate fibres about 2–5 millimetres (0·08–0·2 inch) long, which are polygonal in transverse section and have a large polygonal lumen. The fibre substance consists of a lignified form of cellulose. The commercial value of the product depends chiefly on its length, strength, colour, and freedom from pulpy matter of the leaves which sometimes adheres to the fibre owing to inefficient cleaning.

Commercial Value

The market price of the fibre fluctuates in sympathy with that of Manila hemp. The average value of the best Mexican Sisal hemp on the London market during the years 1907–1914 was about £25 per ton. The best fibre from East Africa usually realises £1 or more per ton in advance of that of the Mexican product. The extent to which the price is liable to fluctuation is illustrated by the following statistics. During 1908, Mexican Sisal was quoted at from £25 to £27 per ton. In 1909, the price fell gradually from £26 in January to £24 in April, and then rose rapidly to £29 10*s*., and remained at that figure from June to December. During 1910, the value gradually declined from £29 10*s*. in January to £20 in December. In the first half of 1911, the price was about £19–£20, but rose during the second half of the year to £22 10*s*. During the months of January to June 1912, quotations varied from £24 10*s*. to £25 10*s*., but during the latter half of the year the value rose to £37 10*s*. in November, and subsequently fell to £35 10*s*. per ton. The price remained at about this figure until September, 1913, and then fell until in December the fibre was quoted at about £28 per ton. In 1914, prices declined somewhat during the first six months of the year, remained at about £26 10*s*. during July and August, and during the last four months fluctuated between £20 and £25 per ton. During 1915 considerable embarrassment was caused in the trade, owing to the political situation in Mexico and the increased freights due partly to the European war, and prices were therefore very erratic and uncertain, rising towards the end of the year to about £38 per ton.

Utilisation of Sisal Refuse

In the course of extracting the fibre from agave leaves, a large quantity of refuse is produced. A good deal of consideration has been devoted to determining the best way of utilising this material. At the present time, the greater part of it appears to be used in the plantation itself for application to the soil. It has been stated, however, that it is better to dry and burn the refuse and employ the ashes as a manure than to apply the fresh or dried refuse directly to the soil. Lommel (*Der Pflanzer*, 1911, VII, 531) has found that 100 lb. of the dry refuse yield about 13 lb. of ash, which contains about 80 per cent. of carbonate of lime, 11 per cent. of carbonate of potash, and 4 per cent. of phosphate of lime.

The refuse has also been suggested as a possible material for paper-making, and it has been stated that a company has been formed in Mexico for the utilisation not only of the leaf refuse but also of the stumps of the plants for the purpose. It is proposed to erect a mill in Yucatan, capable of working up 15 to 20 tons of the raw material per day. The work is to be restricted at first to the manufacture of half-stuff for export. Trials have been made at a mill in New Orleans, which show that the material yields a very strong paper.

It has also been suggested that the leaf refuse could be used as a source of alcohol, but considerable difficulty is found in fermenting it. It may be mentioned, however, that a factory has been established in Mexico for this purpose.

A patent has been taken out in Germany for the extraction of oxalic acid and a wax, resembling Carnauba wax, from the refuse.

The utilisation of Sisal leaf waste in the fresh form as a feeding stuff for stock is reported to have given fairly satisfactory results. The waste contains a moderately high percentage of sugar, and it has been thought that it might also give good results when used in the dry form and in admixture with other food materials.

Sisal Hemp in West Africa

In 1890 specimens of the leaves of an agave were received in this country from Sherbro in Sierra Leone where the plant is known as "Wild Sarsaparilla." The leaves were identified at Kew as those of a form of *Agave rigida* (*Kew Bulletin*, 1892, p. 36), and it was evident, therefore, that at some time or other the Sisal hemp plant had been introduced into West Africa. It is not improbable that the agave would be well adapted to cultivation in some parts of the country.

A small sample of Sisal hemp was forwarded from Sierra Leone to the Imperial Institute in the early part of 1907, and consisted of fairly lustrous fibre which was well cleaned and prepared, and was of fair strength, but of somewhat uneven colour and only 22–27 inches long. The product was regarded as worth about £28–£30 per ton, but if it had had a length of about 4 feet its value would have approximated to that of Mexican Sisal hemp, which was then quoted at about £35 per ton.

Experiments in Sisal hemp cultivation are being made in the Northern Territories, Gold Coast, but the plants are not yet ready for cutting.

During recent years, Sisal hemp has been grown on a small scale in Togo; a consignment exported in 1912 was considered to be equal in quality to the fibre produced in German East Africa. Experiments on the cultivation of the Sisal agave have also been carried out in Dahomey, and in Senegal and the French Sudan.

Zapupe Fibre

Reference may be made here to a fibre closely allied to Sisal hemp and known as "Zapupe" fibre. The name "Zapupe" has been applied to several species of Mexican agaves, of which *A. Zapupe* and *A. Lespinassei* are the most important. The former is known as the "blue Zapupe" or "Estopier," whilst the latter is the "green Zapupe" or "Tepezintla." The fibre has lately been produced on a commercial scale in the neighbourhood of Tuxpam and also in the northern parts of Vera Cruz. It is claimed that the plant bears leaves ready for cutting at a much earlier age than the Sisal agave, that it gives a larger yield of fibre per plant, and has a greater longevity. The fibre is of excellent quality and equal in value to Sisal hemp; the strands are usually somewhat finer than those of the latter fibre.

MAURITIUS HEMP

The Mauritius hemp plant, *Furcræa gigantea*, is a member of the same natural order as the agaves, viz. Amaryllidaceæ, and has a similar habit. It has thick, fleshy leaves and produces an inflorescence or "pole," which reaches a height of 20 to 30 feet and bears numerous bulbils. The life of the plant is usually about seven to ten years, and leaves can therefore be cut for about four or five years before the plant "poles" and afterwards withers and dies.

Furcræa gigantea occurs widely in tropical America, and has been introduced into Mauritius, St. Helena, India, Ceylon, Algeria, Natal, Nyasaland, the East Africa Protectorate, Uganda, Rhodesia, the West Indies, Australia, and other countries.

The fibre is produced in commercial quantities chiefly in the island of Mauritius, although there is no doubt that it could be readily grown in many other countries.

The plant is known in Mauritius as "aloës" and is said to have been first introduced into the island from South America about the year 1790 as an ornamental garden plant. In 1837 it had established itself in several parts of the island, and, although receiving no attention, it gradually spread over waste lands and abandoned sugar estates, until in 1872 the plants were so abundant as to suggest their utilisation for the extraction of fibre. An industry was started about the year 1875, and has continued up to the present time.

Until recently, little, if any, systematic cultivation was practised in Mauritius, but during the last ten years plantations have been established, and it has been found that better results can be obtained in this way than by depending on the wild plants. The plant is found more or less in all parts of the island, and especially on the uncultivated coast lands. It reproduces itself by means of the bulbils, which fall to the ground in sufficient quantities to ensure rapid multiplication.

The fibre is usually extracted in Mauritius by means of the machine known as the " gratte " or " scraper," which is manufactured locally and somewhat resembles the raspador which is so largely used in Mexico for the preparation of Sisal hemp (page 175). After leaving the machine the product is thoroughly washed with water, then soaked in a soap solution for 36–48 hours, again washed with water, and afterwards hung on wooden rails to dry in the sun. It is then brushed and made into bales of about 500 lb. for export. The fibre is classed according to its colour into " prime," " good," " good fair," and " fair " grades.

The yield of dry fibre from the fresh leaves usually varies from 2 to 2·5 per cent., whereas in the case of Sisal hemp a yield of about 3 per cent. or more is obtained. It is probable that one acre of planted *Furcræa* would give about 50,000–60,000 leaves, yielding from ¾ to 1 ton of marketable fibre.

The quantities and value of the fibre exported during the years 1894–1915 are given in the following table :

Year.	Tons.	£	Year.	Tons.	£
1894 .	844	11,435	1905 .	1,648	36,202
1895 .	1,291	27,116	1906 .	1,919	47,282
1896 .	950	16,889	1907 .	2,834	63,231
1897 .	1,165	16,167	1908 .	2,108	39,966
1898 .	1,472	28,475	1909 .	1,849	33,897
1899 .	2,214	37,735	1910 .	1,989	41,833
1900 .	3,056	62,695	1911 .	2,104	40,371
1901 .	1,223	22,623	1912 .	2,214	45,465
1902 .	2,111	60,120	1913 .	2,867	56,904
1903 .	1,495	35,335	1914 .	1,869	38,948
1904 .	1,890	40,225	1915 .	1,313	31,742

The product is almost entirely shipped to the United Kingdom, whence the greater part of it has been usually re-exported, mainly to Germany.

It is evident from these figures that the prices obtained for Mauritius hemp are liable to considerable variation. These fluctuations, like those of Sisal hemp, take place more or less in accordance with the Manila hemp market. The values of all these fibres in London were very high at the end of 1905 and the beginning of 1906, when "good fair" Mauritius hemp was quoted in London at about £30 per ton. The price fell rapidly during 1907, until in March 1908 it had reached £19 10*s*. per ton. The value then remained fairly constant, fluctuating between £19 and £21 10*s*. until the latter part of 1909, when a gradual rise took place. During 1910, the price varied between £24 and £27, and in 1911 between £23 and £25. The value rose slightly during 1912, reaching a maximum of £28 10*s*. in November and falling to £27–£27 10*s*. per ton in December.

During 1913 and 1914, "prime" qualities fluctuated between £26 and £32, "good white" between £23 and £28 10*s*., and "fair" between £21 and £26 per ton. Towards the end of 1915, the price of "prime" rose to £34–£36, and that of "good white" to £32–£34 per ton.

Mauritius hemp resembles Sisal hemp in its general properties, but is usually somewhat finer, softer and weaker than the latter. It is chiefly employed for rope manufacture, and especially for mixing with Manila and Sisal hemps for the production of medium grades of cordage.

It does not seem likely that any great extension of the *Furcræa* industry will take place in Mauritius. There is no doubt, however, that the plantations which are being established will involve only a small expense for cultivation and upkeep, and this will be largely compensated by the diminution in the cost of collection and transport of the leaves, which usually forms a considerable proportion of the cost of production, owing to the plants being distributed over wide areas and often at a great distance from the factory. It is recommended that the plants should be laid out in rows about 4 or 5 feet apart, and with the same distance between successive plants in each row. It is stated that the leaves can be cut about four years after planting, and subsequent cuttings made every eighteen to twenty-four months until the plant dies.

About thirty years ago, *Furcræa gigantea* was introduced into Natal and has since spread along the coast lands. A serious attempt was made about twelve years ago to cultivate the plant in the vicinity of Port Shepstone. Plantations were established, encouragement was given to the settlers to plant small areas with this crop, and a mill was erected and equipped with the needful machinery. The plantations were afterwards neglected, but were reclaimed in 1906, and modern machinery was installed. The transport of the leaves to the factory was found to be a heavy expense, but this could have been considerably reduced, either by laying down tram-lines or erecting machinery in the plantations. With regard to the collection of the leaves, it was found that the best results were secured by cutting from seven to nine leaves each month. About 1,000 acres are now devoted to the crop, and the average yield is about one ton of dry fibre per acre. A small export trade has been established, and the product has realised good prices in the London market.

Furcræa gigantea also grows well in Nyasaland, and produces fibre of excellent quality throughout the Protectorate up to elevations of 2,900 feet. During the last few years, plantations have been established, especially in the Blantyre district, and small quantities of the fibre are now being produced for export.

Another species, *F. cubensis*, grows readily in Tobago and Trinidad and in many other tropical countries, and is said to yield a strong, lustrous fibre. The yield of dry fibre varies from 2 to 3 per cent. of the weight of the fresh leaves.

The cultivation of Mauritius hemp does not appear to have been attempted in British West Africa, except on a small experimental scale in parts of Nigeria and in the Northern Territories, Gold Coast. Experiments have been carried out in Senegal, however, and have given very satisfactory results.

Samples of the fibre of *Furcræa cubensis* were forwarded to the Imperial Institute from Sierra Leone in 1902 and 1905. It is stated that the plant from which this fibre was derived is not indigenous to the country, but was probably introduced from Kew. The fibre was 3–4 feet long and of satisfactory colour, but was inferior to that of *F. gigantea*.

BOWSTRING HEMP (*Sansevieria* spp.)

There are numerous species of Sansevieria (natural order Liliaceæ), the leaves of which yield fibre suitable for use in cordage manufacture and known as "bowstring hemp." These plants are abundant in tropical Africa, and also occur in Ceylon, India, the Dutch East Indies and China. The fibres resemble Sisal hemp in general properties, but there is a considerable diversity in character between the products derived from different species. The leaves arise from the base of the plant, and vary in length from 2 to 6 feet or more. They are of a fleshy and succulent nature, but whilst those of certain species, such as *S. guineensis*, are comparatively flat and wide, others, such as those of *S. Ehrenbergii*, are thick and narrow. The plants possess large, thick underground stems or rhizomes which, in some species, throw out more or less numerous branches.

The Sansevierias require a temperature of not less than 60° F., and demand a humid climate and a certain amount of shade. Most species prefer a rich, moist, loamy soil, but *S. Ehrenbergii* generally grows on arid land. When planted in a favourable environment, the plants grow rapidly and become permanently established by means of their rhizomes. Hitherto fibre has been extracted from wild plants only, but in order to create a lasting industry it would be necessary to have recourse to systematic cultivation. Propagation can be effected by means of cuttings of the rhizomes; in some cases the leaves, or portions of them, if embedded in moist earth to a depth of about 2 inches, will throw out fibrous roots and subsequently develop suckers.

The fibre is extracted from the leaves of these plants by methods similar to those employed in the preparation of Sisal hemp.

Several species of Sansevieria, including *S. guineensis, S. Ehrenbergii, S. cylindrica, S. sulcata, S. Stuckyi* and *S. Volkensis*, grow wild over extensive areas of the East Africa Protectorate, and in 1905 the extraction of fibre, chiefly of *S. Ehrenbergii*, was undertaken on a commercial scale in the neighbourhood of Voi. An account of this enterprise will be found in the *Bulletin of the Imperial Institute* (1907, V, 24–31). More recently, however, the preparation of this fibre has declined and attention has been transferred to the cultivation of Sisal hemp (see page 170).

Sansevieria Ehrenbergii grows over large areas in elevated and moist districts of Somaliland, and during 1908–1910 some quantity of the fibre was prepared and exported. The industry has now been abandoned. This fibre has also been extracted in Abyssinia.

The fibre of *S. Ehrenbergii* possesses a peculiarity which seems to be a definite characteristic of the product of this particular species, and consists of a very marked variation in the diameter of the fibrous strands or filaments. The fibre from the interior of the leaf is fine, whilst that from the more external portions is very coarse. The diameter of the finer fibre varies from about 0·001 inch to 0·0055 inch, whilst that of the coarser strands attains to as much as 0·018 inch. In preparing the fibre for the market, the greater part of the finer fibre is usually combed out and lost.

S. cylindrica is found in Africa from Zanzibar in the east to Angola in the west. Small quantities of the fibre have been exported from Angola, where it is known as " Ifé " hemp.

Sansevieria guineensis has a wide distribution, and is found in Central America, the West Indies, West and East Africa and Mauritius. In the Zambesi region, the fibre is known as " Konje " hemp. The fibre is white, fine, of even diameter and of excellent strength.

This species grows under the shade of trees in a narrow belt along the coast of Sierra Leone. It also flourishes in inland districts, and has been cultivated at Lumley and Mabang. In order to create a profitable industry in this fibre, it would be necessary to employ machinery for its extraction, but the plants are not sufficiently abundant in any one locality to warrant the introduction of machines. Facilities have been offered by the Government for the establishment of plantations, but these have not been taken advantage of to any great extent. Samples of fibre of *S. guineensis* from Sierra Leone and from the Gold Coast have been examined at the Imperial Institute, and found to be of excellent quality and suitable for use with the finest Manila hemp. Specimens of the fibre have also been received at the Imperial Institute from Southern Nigeria under the name of "Ojakoko" fibre.

S. Roxburghiana has long been grown in India and the fibre, known as "Murva" fibre, is used by the natives for making ropes, mats and coarse cloth. The leaves are from 3 to 4 feet long.

S. zeylanica, another Indian species, which is cultivated in Ceylon, bears leaves which are only about 2 feet long and are therefore of less value for fibre.

NEW ZEALAND HEMP

The fibre known as New Zealand hemp or New Zealand flax is obtained from the leaves of *Phormium tenax*, a member of the natural order Liliaceæ. It was first introduced to the notice of Europeans by Captain Cook, who states (*A Voyage to the Pacific Ocean*, 1785, vol., i., p. 149) that there is a plant "which deserves particular notice here, as the natives make their garments of it, and it produces a fine, silky flax, superior in appearance to anything we have, and probably at least as strong. It grows everywhere near the sea, and in some places a considerable way up the hills, in bunches or tufts, with sedge-like leaves, bearing on a long stalk yellowish flowers, which are succeeded by a long, roundish pod, filled with very thin, shining, black seeds."

The plant exists in several varieties. The long sword-shaped leaves grow in opposite rows and clasp one another at the base; each leaf is folded in two longitudinally, the outer surface being shiny and the inner surface dull. The leaves of some varieties are from 5 to 6 feet or more in length, whilst those of others are much shorter.

The smaller varieties are grown on high and dry lands; they yield a finer fibre and are much more easily stripped than the larger plants grown on marshy land.

Phormium tenax is indigenous to New Zealand, and is also found in Norfolk Island and other parts of Australia. It has been distributed to the Azores, St. Helena, Algeria, the south of France, Natal, South India, and California. The plant has also been introduced into the south of Ireland, and flourishes on the south-west coast of Scotland. It is planted in the Scilly Isles in order to resist encroachments of the sea, and has been cultivated in the Orkney Islands.

In the south of New Zealand the plant is not found far from the sea nor at a great elevation; in the North Island it grows best near the coast, but is also found abundantly in the interior up to a height of 2,000 feet.

Cultivation

In order to obtain *Phormium tenax* fibre of good quality, the plant must be cultivated on suitable soil, although almost any soil is capable of supporting its growth. The plant thrives best on a rich, moist, well-drained soil, and is found in its greatest luxuriance in the vicinity of swamps and rivers upon moist, alluvial soil. It also grows well on a rich, dry, clay soil with a yellow clay sub-soil, especially if sheltered from the wind and at the same time provided with plenty of light and air. The plant does not give good results on stagnant marshes, but grows well after such swamps have been drained. Drainage is effected by means of open trenches of a depth sufficient to keep the water about 12 inches below the surface. In the dry summer months these drains may be temporarily stopped, if desired, in order to irrigate the soil. Alluvial soil is ploughed in the winter or spring, and left to dry until the autumn, when it is again ploughed. Planting is then carried out, usually in March or April, when the autumn rains commence. Early planting is advantageous, as the plants put out roots during the winter and are thus enabled to grow vigorously with the advent of spring.

Propagation can be effected by means of seed or by division of the roots. The former method is not satisfactory, since the early growth of the plant is very slow and the seedlings are apt to develop characters different from those of the parent plants. The usual plan is to plant out the roots at a distance of 6 feet from one another in rows 6 feet apart, this arrangement giving about 1,000 plants to the acre. It is not improbable, however, that it would be more advantageous to allow not more than 4 feet between the rows and 3 feet between consecutive plants, as in this case the plants would shelter one another and would produce finer fibre, whilst at the same time a larger crop would be obtained per acre. Should the land become impoverished as a result of planting so closely, manuring must be resorted to. According to another method, ten or twelve rows of plants are set in close proximity, and then a road-space of 10 or 12 feet is left in order to facilitate the gathering of the leaves.

One Phormium plant yields from twenty to thirty roots suitable for transplanting. Some difference of opinion exists as to the number of roots which should be planted together. If the plants are being set wide apart, two or three roots may be placed in one spot, but if close planting is adopted, one root is sufficient. Care must be taken to avoid planting roots which have borne a seed-stem or those from the centre of an old plant, since these are not so productive and are liable to flower, the nourishment being thereby diverted from the leaves. Flower-stalks must be removed as early as possible, and the wound rubbed with a little dry earth to prevent "bleeding."

The *Phormium tenax* plants usually grow together in tufts or bunches containing, on the average, ten shoots, each bearing five leaves; thus each group of plants has about fifty leaves. The leaves vary in length from 3 to 10 feet, and are not ready for cutting until the plants are from five to eight years old, according to the conditions under which they are grown. In New Zealand the leaves are usually cut in December or January. If two or three of the centre leaves of each plant are left untouched, a crop of three or four leaves can be obtained each year.

The suitability of the leaves for cutting is judged by their texture and firmness, or by a splitting at the apex, or the recurving of the blade from the midrib. As already stated, only the outer leaves should be cut; in order not to injure the leaves enclosing the central shoot, the knife is inserted between the leaves, and the outer leaves are cut downwards and outwards.

Preparation of the Fibre

The method of extraction practised by the natives, who use only the upper part of the leaf and only one side of it, consists in scraping away the softer tissues with the edge of a mussel-shell and subsequently soaking the fibre in water and drying it. Early in the last century considerable quantities of fibre were prepared in this way, 60 tons, of total value £2,600, being exported in 1828, 841 tons in 1830, and no less than 1,062 tons in 1831. The fibre thus produced by the natives is of much finer quality than that obtained by the use of machinery.

There are several machines which are used for extracting New Zealand hemp, but they are all constructed on the same principle. The leaf is introduced between horizontal, fluted, revolving feed-rollers, by which it is crushed and held securely while being scraped. As it passes out, the epidermis and parenchymatous tissue are stripped off by means of a beating-drum, revolving more rapidly than the feed-rollers and carrying flanges on its periphery which press the leaf against a bar and thus exert a scraping action. An arrangement is provided for adjusting the distance between this bar and the drum, so that neither can the leaf pass through unstripped nor the fibres be cut. Vulcanised indiarubber cushions or steel springs are placed over the journals of the upper

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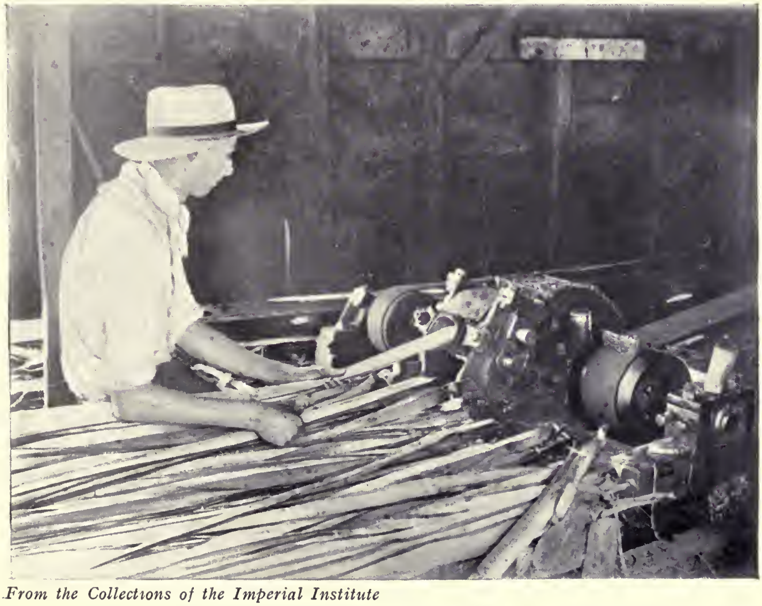
HARVESTING NEW ZEALAND HEMP LEAVES



From the Collections of the Imperial Institute

STRIPPING NEW ZEALAND HEMP

feed-roller so as to accommodate the varying thickness of the leaves. The quality of the fibre produced depends largely on the form of the scrapers or beaters and the speed of revolution of the drum, but more on the ease and accuracy with which the machine can be adjusted.

After leaving the machine the fibre is cleaned by means of revolving brushes, which brush off all the pulpy matter left on it from the stripping-drums. The product is, in some cases, passed through a "finishing" machine, by which the strands of fibre are divided into finer filaments. The fibre is soaked in water for a time, then spread out in the sun to be bleached, and afterwards hung on lines to dry. The dry fibre is made up into hanks of about 5 lb. each, and these are packed in bales of about 400 lb. and pressed for shipment.

Yield

The yield of fibre from the green leaf of *Phormium tenax* is usually given as about 10 to 14 per cent.

It is stated that there is a great difference in the yield per acre afforded by ordinary swamp flax, that is, Phormium grown in the ordinary way, and the cultivated plant. The average yield of green leaves from an acre of uncultivated flax is 10 to 15 tons, rich lands sometimes furnishing as much as 25 tons, whilst an acre of cultivated flax grown on good soil yields 45 to 55 tons. Moreover, the cultivated plant gives a much higher percentage of fibre; the yield is one ton of fibre from 7 tons of leaves of the cultivated plant, and one ton from 8 or 9 tons of uncultivated. The fibre from the cultivated plant is also of better quality than that from the uncultivated.

The cost of production varies to some extent according to the locality and the conditions, but it has been estimated that at Wairoa a ton of fibre ready for shipment costs about £14 to produce.

Characters, Properties and Uses of the Fibre

New Zealand hemp is a lustrous, soft, flexible fibre and varies in colour from nearly white to pale reddish-brown.

The bundles of ultimate fibres form filaments of unequal thickness, but these filaments can be separated into finer strands by friction. It is for this reason that the hand-prepared fibre is so much finer than that prepared by machinery. The former is said to be as soft as fine flax, and suitable for the manufacture of fine textiles. The machine-prepared fibre, however, being coarser, is chiefly used for the manufacture of rope, twine, and floor-matting.

Microscopical examination shows that the ultimate fibres vary from 0·12 to 0·75 inch in length, and from 0·0004 to 0·0008 inch in diameter, and are regular and uniformly thickened. The surface is smooth and free from markings or striations. The fibre substance is strongly lignified.

Production and Export

When the colonists first arrived in New Zealand, the valuable qualities of the Phormium fibre were well known, as it was in constant use by the natives, and constituted the first article of barter in the trade carried on by the Maoris with Europeans. A very considerable trade in the fibre existed as early as 1828 (see p. 190), when the Islands were only visited by whalers and Sydney traders, £50,000 worth being sold in Sydney between 1828 and 1832. A factory for the manufacture of articles from New Zealand hemp was established at Grimsby in Lincolnshire in 1832, but failed for some unexplained cause, notwithstanding that the results at the time were regarded as satisfactory. From 1853 to 1860 the average annual value of the fibre exported was £2,500 reaching as much as £5,000 in 1855; but up to that time the only fibre exported was that prepared by native labour, no machinery of any kind being used. In 1860, therefore, when the native disturbances affected the

PLATE XI

From the Collections of the Imperial Institute

DRYING NEW ZEALAND HEMP

From the Collections of the Imperial Institute

GRADING NEW ZEALAND HEMP

Waikato and other interior districts of the North Island, the production was confined to the native tribes north of Auckland, so that in 1861 the export fell to two tons, of value £43. Attempts were then made to devise machinery by means of which the fibre could be profitably extracted by European labour. About this time the increasing demand for white rope and the limited quantity of Manila hemp available led to a rise in the value of New Zealand hemp from £21 to £56 per ton, and even to £76 in America during the Civil War. These high prices stimulated the endeavour to introduce Phormium to compete with Manila, and several machines were invented for producing the fibre rapidly from the green leaf. With these machines the export trade again increased, so that from 1866 to 1871 the yearly average was about £56,000. The total quantity exported between 1864 and 1876 amounted to 26,434 tons, valued at £592,218.

In order to encourage the industry, the New Zealand Department of Agriculture has repeatedly offered bonuses for a machine or process which should be an improvement on the machines or processes in use, and which should be found to reduce materially the cost of production, improve the product, or increase the yield of dressed fibre. Another bonus has been offered for a process for utilising the waste products of the hemp. As a result of these offers, improvement has been effected in various machines, including those for converting scutching waste into marketable tow and those for washing and trimming the fibre, whilst a new automatic scutching machine has been invented.

Grading

Owing to the complaints of rope and cordage manufacturers with regard to the lack of uniformity in New Zealand hemp, parcels bought under the same classification and shipped from the same port varying in colour and preparation, the Government passed an Act in 1901 providing for the establishment of a grading station for the compulsory grading of all hemp exported. As a result of this, the quality of the fibre rapidly improved, and the confidence of buyers was secured. The system employed in grading hemp for shipment consists in giving points according to the following scale :—

Stripping, 25 ; colour, 25 ; scutching, 25 ; strength, 25 ; total, 100.

The highest grade, "superior," must score 90 marks or over ; "fine," 80–89 ; "good fair," 70–79 ; "fair," 60–69 ; "common," 50–59 ; "rejected," under 50. To each bale a tag is affixed stating the grade of the fibre and bearing the signature of the grader.

The compulsory grading system has now been extended to tow, according to the following scheme : No. 1 Grade, 80–100 marks ; No. 2 Grade, 60–79 ; No. 3 Grade, 40–59 ; below 40 marks, condemned as unfit for export. By far the greater part (over 90 per cent.) of the New Zealand hemp exported is of the "good fair" and "fair" grades.

Exports

The following table gives the quantity and value of the exports of New Zealand hemp for every fifth year from 1856 to 1906, and for each year from 1909 to 1915 :—

Year.	Quantity. *Tons.*	Value. £	Year.	Quantity. *Tons.*	Value. £
1856 .	22	552	1901 .	10,171	195,728
1861 .	2	43	1906 .	27,779	776,106
1866 .	45	996	1909 .	14,318	306,973
1871 .	4,248	90,611	1910 .	20,645	448,414
1876 .	897	18,285	1911 .	17,366	300,201
1881 .	1,308	26,285	1912 .	18,461	367,264
1886 .	1,112	15,922	1913 .	28,092	721,924
1891 .	15,809	281,514	1914 .	19,702	455,214
1896 .	2,968	32,985	1915 .	23,220	571,621

In 1913, 28,092 tons of New Zealand hemp of value

£721,924, and 6,299 tons of tow of value £65,138 were exported and were distributed as follows :

Destination.	Hemp.		Tow.	
	Tons.	£	Tons.	£
United Kingdom	20,992	538,324	5,395	55,059
United States	3,056	79,057	3	12
Victoria	2,149	56,293	598	6,670
New South Wales	1,513	38,274	278	3,105
South Australia	170	4,649	10	117
Western Australia	108	2,994	10	126
Tasmania	1	12	5	49
Canada	51	1,070	—	—
Belgium	25	683	—	—
Holland	25	497	—	—
Japan	2	71	—	—
Total	28,092	721,924	6,299	65,138

Commercial Value

The commercial value of New Zealand hemp is liable to considerable variation as it fluctuates in sympathy with that of Manila hemp. The following are the prices at which the "good fair" and "fair" grades have been quoted in London in February of the years 1907–1916 :—

	Good Fair. per ton.		Fair. per ton.	
	£	s.	£	s.
February 1907 . .	40	0	36	15
„ 1908 . .	27	15	26	15
„ 1909 . .	24	0	22	15
„ 1910 . .	26	15	25	15
„ 1911 . .	19	10	19	0
„ 1912 . .	21	15	20	5
„ 1913 . .	34	10	32	10
„ 1914 . .	26	0	23	10
„ 1915 . .	29	0	27	10
„ 1916 . .	48	0	46	0

Cultivation and Production in St. Helena

Phormium tenax has been planted somewhat largely in St. Helena and was cultivated successfully during the years 1876–1880. The largest amount of the fibre exported in any one year was 615 bales in 1879, and the greatest value of the export (£1,890) was reached in 1880. A factory was established at Jamestown for extracting the fibre, but as this was several miles distant from the plantations the cost of transport absorbed all the profit.

The question of reviving this industry in St. Helena came to the front in 1904, and in 1905 an attempt was made to extract the fibre on a commercial scale. This effort did not meet with much success, owing partly to the difficulty of raising the necessary capital, and partly to the fact that the machinery purchased was not altogether satisfactory.

A further endeavour has been made in recent years to re-establish the industry with Government assistance and under the guidance of an expert from New Zealand. A fibre mill was established by the Government in 1908 and another mill was started by a private firm in 1913. Very satisfactory results have been obtained. In 1913, 1,296 tons of *Phormium tenax* leaves were treated at the Government mill with the production of 128 tons of fibre and 39 tons of tow. The fibre realised an average price of £28 10*s*. per ton and the tow £14 10*s*. per ton. Almost exactly the same quantities were produced in 1914. In the latter year, the private mill treated 1571 tons of the green leaves and produced 177 tons of fibre and 45 tons of tow. The total exports of fibre and tow in 1914 amounted to 347 tons, of value £7,439.

Cultivation in the Azores

The cultivation of *Phormium tenax* is now being carried on in the Azores. The plant is said to grow well in all parts of the island of St. Michael, and the leaves vary in length from 6 to 8 feet. A factory has been erected and equipped with machinery, and a small export industry has been established.

Cultivation in Scotland

During recent years, experiments have been made with *Phormium tenax* in the South-west of Scotland. Several acres have been planted, extracting machinery has been introduced, and in 1913 a crop of fibre of very satisfactory quality was produced. It has not yet been definitely proved whether it will be possible to establish a remunerative industry, as this will depend very largely on the amount of labour required and its cost.

OIL-PALM FIBRE

The leaflets of the West African oil-palm (*Elæis guineensis*) yield a pale yellowish-green, fine fibre of great strength and excellent quality. Small quantities of this fibre have appeared from time to time on the market, but the cost of production is so great as to make it impossible to prepare it at any but a prohibitive price, even with the advantage of native labour. If, however, a cheap method of separating the fibre from the leaves could be devised, the product would be well worth exporting. The only use to which the fibre has been applied hitherto is for the local manufacture of fishing lines and fine cordage. It is probable that if a constant supply were available for export it would find a ready market.

CHAPTER VIII

MISCELLANEOUS FIBRES

Pineapple Fibre

The leaves of the pineapple, *Ananas sativus*, of the natural order Bromeliaceæ, yield a fine, strong, white, silky fibre.

The pineapple is usually cultivated for its fruit and comparatively rarely for its fibre. Pineapples are grown in large quantities in the West Indies, the Bahamas, Florida, the Philippines, Formosa, Java, India, Indo-China and other parts of the tropics, but the only countries which make much use of the fibre are the Philippines and Formosa. In the Philippines, the natives make beautiful silky fabrics, known as "pina" and "rengue," which find a local market. In Formosa also, the preparation of pineapple fibre is a regular industry, and a quantity of the product is exported to China where it is employed for the manufacture of "grass-cloths" of a particularly high quality. A small amount of the fibre is also produced in Java, but is not exported.

The pineapple does not thrive in wet soils, but is best adapted to a porous, well drained soil, and is capable of withstanding protracted drought. It is usually propagated by means of the suckers which arise from the parent plant near the ground, but it can also be reproduced by means of slips. The plant cannot be grown satisfactorily for both fruit and fibre, but when it is being cultivated for the latter, the fruit is removed soon after flowering has taken place in order that the leaves may develop more freely. Moreover, the best fibre is produced by plants grown in the shade, whereas the fruits require to be exposed to the sun in order to ripen properly.

The fibre is extracted in a very primitive manner. In Formosa, the fresh leaves are laid on a board and scraped with a potsherd, the fibre being thus freed from the epidermal and pulpy tissues. In the Philippines, the epidermis is first removed from the leaves by means of a blunt iron or wooden scraper. A layer of fibre is thus exposed, and is lifted with the fingers or a flexible knife. The scraping is then repeated, and a second layer of fibre is exposed which is removed in turn. This process is continued until the whole of the fibre of the leaf has been extracted. After the fibre has been extracted it is washed with water and dried and bleached by exposure to the sun. The yield amounts to from 45 lb. to 65 lb. of dry fibre per ton of fresh leaves.

Attempts have been made to prepare pineapple fibre by means of machinery, but hitherto the machines tested have not proved commercially successful. The difficulty of obtaining a satisfactory machine is due very largely to the peculiar structure of the leaf. The upper surface is much more tender than the lower which is more or less coriaceous. The fibres are situated chiefly near the two surfaces and less abundantly in the centre of the leaf. It is therefore evident that a machine capable of stripping the epidermis from the lower surface would tend to tear away some of the fibre from the upper surface and thus create a good deal of waste.

Pineapple fibre is soft, fine, strong, white and lustrous, and may be 3½ feet or more in length. It would probably serve as a substitute for flax. Small samples which have been received in London from time to time have been valued nominally at prices varying from £20 to £40 per ton. A specimen received at the Imperial Institute from the Gold Coast in 1907 consisted of soft, white, lustrous fibre of even diameter and good strength, and about 3½ feet long.

The ultimate fibres are remarkable for their extreme fineness. They are from 0·12 in. to 0·36 in. long, with an average of 0·25 inch, and have a diameter of

0·00012 in. to 0·00036 in. with an average of 0·00020 inch. The lumen appears as a mere line.

Although when the pineapple is grown for fruit, its leaves cannot be used for the preparation of fibre for textile purposes, yet it is possible that the leaf refuse from the plantations might be employed to advantage for the production of pulp for the manufacture of paper, and would thus form a valuable by-product of the pineapple industry.

Coir

The fibre known in commerce by the name of coir is derived from the thick fibrous layer which envelopes the coconut.

The coconut palm (*Cocos nucifera*) has become distributed throughout the coast regions of the whole of the tropics and occurs most abundantly on the shores of Southern Asia and the adjacent islands. It is cultivated to the greatest extent in Ceylon, and is also grown very largely in India and in South America.

The fruit of the coconut palm is a drupe. Beneath the outer skin or epicarp is situated the thick fibrous layer, the mesocarp ; and within this is the endocarp or woody shell of the nut which encloses the kernel. There are many varieties of *Cocos nucifera*, but only three of them, viz. var. *rutila*, var. *cupuliformis*, and var. *stupposa*, bear a mesocarp of suitable quality and sufficient size for use in the preparation of coir. The first-named variety is said to furnish the best fibre whilst the last gives a fibre which is harsh and stiff. It is considered that the quality of the fibre is influenced to some extent by the situation of the plantation, coir obtained from palms growing near the sea being finer than that yielded by inland trees.

The fibrous material in its raw state, that is, unbeaten and uncombed, consists of fibres of varying length associated with a quantity of corky and other non-fibrous tissue.

For the preparation of coir the coconuts should be gathered before they are quite ripe. The fibre

From the Collections of the Imperial Institute

COIR. REMOVING THE HUSKS FROM COCONUTS IN CEYLON

From the Collections of the Imperial Institute

PALMYRA PALMS, CEYLON

becomes coarser as the nuts ripen and then requires to be soaked for a longer period in order to free it from the corky tissue, with the result that the coir acquires a dark colour. In the old, native system of treatment, the coconuts are immersed in pits of salt water and left there for several months, but in the preparation of the best commercial coir it is now usual to detach the husks, which is accomplished by striking the nuts on sharp spikes fixed in the ground or by means of a simple machine, and to steep these in large tanks of water warmed by steam. The treatment is much shortened in this way.

After steeping the husks, which facilitates the removal of the corky tissue, they are either beaten by hand with wooden mallets or passed through a crushing machine. The fibre, after leaving the crushing machine, is passed into the extractor or breaking-down machine, in which it is completely disintegrated. The product is then treated by a "willowing" machine to remove the dust and other non-fibrous matter. In order to improve the colour of the fibre, it is sometimes bleached either by exposure to the sun or by treatment with sulphurous acid.

After being cleaned, it is of great importance that the fibre should be sorted. It is usually separated by a process of combing or hackling into two grades. The coarser and stiffer or "brush" fibre is employed as bristles for brush-making, whilst the longer and finer "mat" or spinning fibre is used for the manufacture of matting or ropes. The very short fibres are utilised as a stuffing material in upholstery, and the dust and refuse for gardening purposes.

The recorded estimates of the yield of coir per coconut show great variation, as would naturally be expected since the yield depends chiefly on the size of the coconut. It seems, however, that on the average ten fair-sized coast coconuts furnish about 5 lb. of mat fibre and 1 lb. of bristle fibre.

The commercial value of Ceylon "bristle" fibre in the London market varied during the years 1912–1915 from £18 to £26 per ton according to quality, and that of Ceylon "mat" fibre from £8 to £14 per ton.

Coir is composed of a mass of very strong, elastic filaments of a reddish-brown colour. These filaments are thick in the middle and gradually taper towards the ends, the diameter in the widest part varying from 0·002 to 0·012 inch; they are from 6 to 13 inches long, and either round or elliptical in cross-section. The fibre is very resistant to the action of water, and is so light as to float on it, and it is therefore of great service for the manufacture of ships' ropes.

The individual filaments are composed of fibro-vascular tissue consisting chiefly of very short, irregularly thickened bast fibres of uneven diameter; these ultimate bast fibres are about 0·016 to 0·039 inch long and 0·0005 to 0·0008 inch in diameter.

The importance of the coir industry can be gauged from the following statistics.

Exports of Coir from India

Raw Fibre.

Year.	1908–09	1909–10	1910–11	1911–12	1912–13	1913–14	1914–15
Quantity, tons	491	658	619	564	466	741	247
Value, £ .	6,830	9,458	8,541	7,603	6,532	11,449	3,491

Manufactured Coir (excluding rope).

Year.	1908–9	1909–10	1910–11	1911–12	1912–13	1913–14	1914–15
Quantity, tons	28,753	33,865	32,091	37,420	36,216	38,613	23,793
Value, £ .	418,347	485,736	463,623	538,967	550,486	592,741	380,299

Exports of Coir (Raw and Manufactured) from Ceylon

Year.	1909	1910	1911	1912	1913	1914	1915
Quantity, tons	14,105	15,461	15,900	18,408	19,487	17,712	15,744
Value, £ .	172,139	197,278	175,694	203,239	222,476	188,512	143,082

The exports from Ceylon in 1914 were composed of :

	Quantity. Tons.	Value. £
Coir Fibre . .	11,397	86,157
,, Rope . .	852	11,354
,, Yarn . .	5,456	90,790
Other forms . .	7	211
Total . .	17,712	188,512

The above figures do not include the small quantities of coir matting which are exported, the values of which in 1911–1914 were as follows : 1911, £473 ; 1912, £488 ; 1913, £378 ; 1914, £695 ; 1915, £361.

Imports of Coir into the United Kingdom

Raw Fibre.

From	1907	1908	1909	1910
	Tons.	*Tons.*	*Tons.*	*Tons.*
British India . . .	398	268	305	289
Ceylon	1,101	595	50	53
Other British Possessions .	6	—	—	—
Foreign Countries . .	68	51	19	6
Total . . .	1,573	914	374	348
Total Value, £ . .	16,310	9,057	5,240	5,004

The raw fibre was not separately enumerated in the official statistics after 1910.

Yarn.

From	1908	1909	1910	1911	1912	1913	1914	1915
	Tons.	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*	*Tons.*
British India .	11,300	13,528	11,013	12,759	11,115	12,578	8,567	21,715
Ceylon . .	4,446	3,653	3,701	3,760	3,749	3,761	3,042	3,459
Germany and other Foreign Countries .	372	115	170	231	331	272	384	64
Total .	16,118	17,296	14,884	16,750	15,195	16,611	11,993	25,238
Total Value, £	273,754	289,998	245,345	292,684	279,966	332,738	247,268	530,342

Piassava

Piassava is the name applied in commerce to the long, stiff, elastic strands, usually about 2 or 3 feet long, and $\frac{1}{30}$ in. to $\frac{1}{12}$ in. in diameter, which are produced by certain palms, and are used extensively for the manufacture of brooms and brushes. The product is derived from the sheathing leaf-bases which clasp the trunk of the palm-tree. After the leaves have fallen, a portion of the dilated leaf-stalk remains attached to the stem ; the softer parts of this structure gradually suffer decay until finally there remain numerous coarse strands composed of the sclerenchymatous tissue of the fibro-vascular bundles. These are at first directed upwards from the trunk, but subsequently bend downwards and give the tree a peculiar, characteristic appearance. The piassava consists of these elastic, wiry filaments which vary in colour from brownish red to dark purplish. The following are the chief commercial varieties.

Bahia Piassava.—This fibre is derived from *Attalea funifera*, a palm which grows in the forests of Bahia, Brazil, to a height of 30–40 feet. The natives cut the long stiff strands from the stem by means of a small axe. The best fibre is obtained from young trees, about six to nine years old. The product is roughly hackled, straightened and cleaned, and pressed into bundles for export. Bahia piassava is chocolate-coloured, a little flattened in form, flexible and very resistant. It is largely used for the brushes of road-sweeping machines.

Para Piassava.—This variety is obtained from *Leopoldinia Piassaba*, a palm growing to a height of 15–40 feet, and occurring abundantly in the White River region and certain other parts of Brazil. The fibre is obtained much in the same way as the Bahia kind. It is strong and black, and is used for making strong brushes such as are used for grooming horses. This product forms only a small proportion of the piassava of commerce.

Madagascar Piassava.—This product is derived from *Dictyosperma fibrosum*, a palm known in the island of Madagascar as "Vonitra." The fibre was introduced into the markets of Europe in 1890; it is of a rich brown colour, and is finer and more flexible than Brazilian piassava, but only 1½ to 2 feet long. Only small quantities of this piassava appear in commerce.

West African Piassava.—Large quantities of piassava are now produced in West Africa from *Raphia vinifera*, the "wine-palm," which occurs abundantly in many parts of the country. It was first introduced into European commerce in 1890 from Liberia, the head-quarters of the industry being situated at Grand Bassa. The large profits obtainable from the collection and export of this product soon attracted attention in other parts of the West Coast and the trade rapidly extended.

The masses of fibrous strands which constitute the sheathing leaf-bases are cut from the trees and immersed in water for a few days until all the non-fibrous matter has decayed. The strands are afterwards cleaned by drawing them through a primitive kind of hackling instrument consisting of nails driven fairly closely together into a board. In some districts, the product is cleaned by drawing the strands through split bamboos which are either held by the feet or stuck into the ground. The fibre is then carefully dried by exposure to the sun. West African piassava varies in colour from light brownish red to deep brown, is 3–4 feet long, and of a stiff, wiry and very resistant nature. It is used chiefly for making brooms and brushes, but can also be employed for the manufacture of baskets, chair bottoms, etc.

In the Ivory Coast, piassava is obtained from *Raphia Hookeri*, but although the palm is very abundant, only small quantities of the product are exported.

Imports of Piassava into the United Kingdom

From	1912		1913		1914		1915	
	Tons.	£	*Tons.*	£	*Tons.*	£	*Tons.*	£
Brazil	1,208	43,365	1,217	44,255	1,274	44,470	1,837	72,157
Liberia	1,573	29,680	1,750	32,183	948	26,685	4,082	116,983
British West Africa	219	4,003	139	2,402	240	9,841	650	18,877

Exports of Piassava from Sierra Leone and Nigeria

From	1912		1913		1914		1915	
	Tons.	£	*Tons.*	£	*Tons.*	£.	*Tons.*	£
Sierra Leone	1,146	15,461	839	12,280	983	19,492	1,283	27,491
Nigeria .	330	4,292	227	2,806	403	5,117	372	5,038

The commercial value of piassava varies greatly with the quality of the product. During the years 1913–1915, the prices generally ranged between the following limits :

Bahia Piassava, £26—£54 per ton.
African Piassava, £18–£36 per ton.

Allied to piassava are certain other fibres used for brush-making, the chief of which are palmyra and kitool.

Palmyra

This fibre is obtained from the sheathing leaf-stalks of the palmyra palm (*Borassus flabellifer*) which grows throughout tropical India, and is also found in West Africa. The product is strong, wiry, and about 2 feet long ; it is sometimes referred to in commerce as "bassine." In transverse section, the fibrous strands are of oval form, the longer diameter being about 0·05 inch, and the shorter diameter about 0·03 inch. The commercial supply of this fibre is derived chiefly from India and Ceylon. The exports from Ceylon, in the years 1912–1915, were as follows :

Year.	Quantity. *Cwts.*	Value. £
1912	1,889	2,175
1913	1,059	1,079
1914	1,784	2,372
1915	2,588	4,228

During the years 1914 and 1915, the prices of palmyra fibre in the London market varied within the following limits : common to fair, £22–£27 ; medium to good medium, £28–£38 ; good to fine, £30–£45 per ton.

Kitool

Kitool consists of the fibre produced at the base of the leaf-stalks of the kitool or jaggery palm (*Caryota urens*), which is distributed throughout tropical Asia, and is commonly met with in the hotter parts of India, Ceylon and the Malay Peninsula. It is much finer than piassava and palmyra, its diameter being about 0·025 inch, and is also softer and more pliable. The strands are straight, smooth, and lustrous, and vary in colour from dark brown to black. The product is strong and elastic, and somewhat resembles horse-hair. In the years 1912–1915, the exports of kitool from Ceylon were as follows:

Year.	Quantity. *Cwts.*	Value. £
1912	2,605	9,213
1913	2,412	8,661
1914	1,864	6,884
1915	1,802	6,697

Small quantities are also exported from India. During the years 1913–1915, the fibre was quoted in the London market at prices ranging from 1*d*. to 11*d*. per lb.

Mexican Fibre

Mexican fibre, which is also known as Istle or Tampico hemp, is obtained from the leaves of certain agaves, of which *Agave heteracantha* is the most important. The plants occur in all parts of Mexico, but chiefly on the plains and mountain slopes of the States of Coahuila, Tamaulipas, Nuevo Leon, and San Luis Potosi. The last mentioned State is the principal centre of the industry, and the fibre from this region is shipped from Tampico.

The soil on which the plants grow is very poor and highly calcareous. The leaves are usually from one to two feet long, and bear sharp spines on their margins. Only the central leaves are gathered, the outer ones being left on the plant as they are too hard to admit of satisfactory extraction of the fibre. After the thorny margins have been stripped off, the leaves are scraped on a hard, wooden block by means of a blunt iron knife, and the fibre thus obtained is subsequently spread out in the sun to dry.

The fibre is commonly known in commerce by the name of the district in which it is produced. The Jaumave fibre is the best quality, the Tula is shorter and coarser, and the Matamoras is rather soft and inferior to the other kinds in length and colour.

The fibre somewhat resembles Sisal hemp in appearance, but is more wiry and of a pale yellow colour. It is in considerable demand as a substitute for animal bristles for the manufacture of cheap scrubbing brushes and nail brushes.

During 1913, the price of Mexican fibre in the London market varied, according to the quality of the product, from £20 to £30 per ton. Towards the middle of 1914, the value of the fibre rose to £40–£60, and during 1915, it was quoted at prices ranging from £32 to £70 per ton.

Italian Whisk or Broom Corn Fibre

The broom corn or broom millet is a variety of *Sorghum vulgare* which has round, cane-like stems, bearing panicles or seed-heads with long, wiry, straight, nearly erect branches which constitute the brush or whisk. The plant is cultivated extensively in the United States, Italy and elsewhere, and is also grown on a commercial scale in New South Wales. It has been cultivated experimentally in the British West Indies and in Nyasaland, and samples of the brush from the latter country have been examined at the Imperial Institute (*Bulletin of the Imperial Institute,* 1915, XIII, 201).

Italian whisk usually consists of 2 or 3 inches of the stem surmounted by a brush of stiff, stout, golden yellow stalks, of a uniform length of about 2 feet. It is employed for the manufacture of the whisk brushes used by hair-dressers, drapers, and others.

Mexican Whisk or Zacaton Fibre

This and similar products are known in France by the name of "chiendents." Mexican whisk consists of the roots of *Epicampes macroura,* a grass with coarse, tufted leaves which occurs extensively in the Mexican highlands and attains a height of 6 or 7 feet. The roots are collected by hand, washed in water, and dried in the sun, and are exported from Vera Cruz under the name of "Raiz de Zacaton"; they are about 9–12 inches long, of pale yellow colour and wavy appearance, and very flexible. The yellow colour is said to be obtained by exposing the roots to the fumes of burning sulphur. They are used chiefly in France and Germany for the manufacture of carpet brooms, clothes brushes, and velvet brushes. The product is not altogether satisfactory, as, when thoroughly dry, the fibres become brittle and are apt to break when being used as brushes.

A product, resembling Mexican whisk, but of superior quality, is obtained from a European grass, *Chrysopogon gryllus.* The roots are collected and treated in much the same way as those of *Epicampes macroura.* The industry is principally carried on in Italy and Hungary.

Flosses or Silk-cottons

The seeds of many plants are enveloped by hairs which facilitate their distribution by the wind. These hairs are sometimes attached to the seed itself, as in the case of cotton, *Calotropis gigantea,* and *Funtumia elastica,* but in other cases arise from the inner wall of the capsule, as in *Eriodendron anfractuosum* and other plants of the natural order Bombacaceæ. Cotton is, of course, the most important of these products, but many of the others have been found useful for various purposes, the chief of them being the flosses or silk-cottons, which are used principally for stuffing upholstery. The flosses are fine, soft, lustrous fibres, but are very weak.

The most valuable of the flosses is the product, known as "kapok," which is derived from *Eriodendron anfractuosum*, a large forest tree, which occurs in the Dutch East Indies, India, Ceylon, West Africa and other parts of tropical Africa, the West Indies, and South America. The commercial supply is obtained chiefly from Java, but small quantities are exported from India and from the Philippines. The greater part of the Indian floss exported, however, is the product of *Bombax malabaricum*.

The kapok tree grows at the sea-level and up to an altitude of 3,000 or even 4,000 feet, but gives the best yield and quality of fibre when situated at less than 1,500 feet above the sea. It is said to flourish best on a porous, sandy clay soil, in a warm climate, and to be capable of withstanding heavy rains and resisting long periods of drought.

The propagation of the tree can be easily effected by means of either cuttings or seed. In the latter case the seed is sown in nurseries, and is only lightly covered with earth. If the soil is poor, stable manure should be applied about ten days before sowing. The seed should be planted in rows about 10 to 12 inches apart. When the young plants are about 5 or 6 inches high, they should be no longer shaded, but exposed to the sun. If the plants do not obtain plenty of sunshine, they grow tall and thin. The seedlings are planted out when from eight to twelve months old. In Java, kapok trees are commonly planted about 12 to 15 feet apart along the roads in the coffee and cocoa plantations. When the trees are grown in special plantations, they should be placed about 18 feet apart (about 144 trees to the acre), for if planted more closely they soon interfere with one another. The trees commonly attain a height of 30 feet, but sometimes grow to 50 feet or even more.

Before transplanting, it is advisable to strip off all the leaves and to cut the stem down to a height of 1½ to 2 feet, and also to cut the chief roots so as to make stumps of them. If the top is not cut it will usually die down to the ground. The trees subsequently require very little attention, but the soil must be kept free from weeds.

During the early years of growth other plants can be cultivated between the young trees. In Java it is a common practice to grow pepper in this way, but it should not be planted before the kapok trees are three or four years old.

The trees begin to bear in the third or fourth year, but sometimes not till later. The crop is never very large until the sixth year. It has been found in Java that a dry fruit weighs on the average about 414 grains and contains 76 grains of fibre. In Cambodge, the average weight of a dry fruit is said to be 494 grains, and the average weight of fibre 107 grains. A well developed tree gives an annual yield of from 2 to 4 lb. of clean fibre.

The tree flowers in April or May, and the fruits mature at the end of October or in November. As the fruit ripens it becomes yellowish-brown, and then begins to open. As soon as this point is reached, the fruits are gathered by means of long bamboo poles bearing small hooks at the upper ends. They are then left on a clean floor, preferably of cement, and exposed to the sun in order that they may ripen completely and open fully. The fibre and seeds are picked out of the capsules by women and children, and are dried in the sun for some days.

The seeds are usually removed from the fibre by beating with sticks or by means of a simple machine. Special machines have been recommended for the purpose, but it must be remembered that in most cases the kapok is only a subsidiary product and produced in small quantities, so that the provision of expensive machinery would not be remunerative.

The kapok is packed in bales by means of hydraulic or hand presses; each bale weighs about 80 lb. It must not be compressed too severely as the fibres are liable to be broken, and this not only impairs the resilience of the material, but also reduces its buoyancy by enabling water to enter the cavity of the fibre. The number of bales exported from Java in recent years is as follows: 1907, 92,874; 1908, 109,852;

1909, 87,685; 1910, 106,442; 1911, 123,295; 1912, 149,610; 1913, 120,710.

The value of the total imports of kapok into the United Kingdom amounted to £27,645 in 1909, £29,020 in 1910, £38,023 in 1911, £44,664 in 1912, £27,458 in 1913, £37,869 in 1914, and £79,002 in 1915.

Kapok consists of pale yellowish, highly lustrous, silky hairs which are unicellular and of cylindrical form. The hairs are from 0·6 to 1·2 inches long, with an average length of 0·75 inch, and from 0·0004 to 0·0012 inch in diameter, with an average of 0·0007 inch. The cell-wall is very thin, and it is for this reason that the strength and durability of the fibre are so small. The base of the hair is dilated and bears annular or reticulate markings, but other parts of the cell-wall are smooth and devoid of markings. The free end tapers gradually to a point. The hairs are straight and do not possess the twist which is characteristic of true cotton. The cells are full of air and are very light; they also possess the property of being impermeable to moisture, and on this account are extremely buoyant. It has been stated that kapok can support about thirty-five times its own weight in water, whereas cork can only carry about five times its weight.

Kapok is employed chiefly as a substitute for hair or feathers for stuffing cushions, pillows, mattresses, chairs and similar articles, and is well adapted for this purpose on account of its lightness, its springy or resilient nature, and its non-hygroscopic and non-absorbent character. Owing to its buoyancy, it is used as a packing material for the manufacture of buoys, life-belts, and life-saving jackets.

Many attempts have been made to employ kapok as a textile material, but considerable difficulty has been experienced which is due chiefly to the fact that the fibres have a smooth, slippery surface and therefore lack cohesive force. The difficulty has been surmounted recently however by roughening the surface of the fibre by chemical treatment, and so enabling it to exert the necessary grip. By a special arrangement and adaptation of the spinning machinery the roughened fibres can be spun either alone or in admixture with cotton. These processes are applicable not only to kapok, but also to many other flosses. The yarns so produced cannot be satisfactorily bleached, but are readily dyed and possess an excellent lustre and a woolly character, and are said to be suitable for the manufacture of plushes, lace and other materials.

During recent years the market value of kapok has fluctuated considerably, as is shown by the following average prices per lb.: Java kapok, 1904–06, 5½*d.*–6*d.*; 1907–1909, 5¾*d.*–6¾*d.*; 1910, 6¾*d.*–7½*d.*; 1911, 8½*d.*–10*d.*; 1912–1913, 7¾*d.*–9*d.*; 1914–1915, 6¾*d.*–7½*d.* Calcutta kapok, 1904–1910, 4½*d.*–5*d.*; 1911, 5*d.*–5½*d.*; 1912–1913, 6*d.*–7*d.*; 1914–1915, 5*d.*–6*d.*

Allied to kapok are many other plants of the Bombacaceæ which bear flosses derived from the inner wall of the capsule. Among these may be mentioned *Bombax* spp., especially *B. Ceiba* of South America and *B. malabaricum* of India, *Chorisia* spp. of South America, *Eriodendron Samauma* of Brazil, and *Ochroma Lagopus* of tropical America and the West Indies.

Various plants of the natural order Asclepiadaceæ, including *Asclepias* spp., *Calotropis gigantea, C. procera,* and *Gomphocarpus brasiliensis,* produce silk cottons attached to the seeds. Reference may also be made to *Funtumia elastica* (Apocynaceæ), the well-known rubber tree of West Africa, and *Cochlospermum Gossypium* (Bixaceæ) which occurs in India. Most of these products are decidedly inferior to true kapok in resilience, and are therefore less valuable for upholstery purposes.

Vegetable Curled Hair

Another fibre used as a stuffing material in upholstery is one obtained from the leaves of the dwarf fan palm, *Chamærops humilis,* which grows wild in some parts of Southern Europe, and is very abundant in Algeria and Tunis. The fibre is extracted by subjecting the leaves to the action of a rapidly revolving drum, the surface of which is studded with spikes.

The leaves are kept moist during the operation by causing a jet of water to play on them. Short, coarse fibres are thus obtained which, after being dried, are twisted together into a kind of rope. The rope is left for a few weeks, and is afterwards untwisted; the fibres then present a crinkled appearance and constitute the material known as "vegetable curled hair" or "crin végétal." The product is used either in its natural or "green" state or is dyed black by means of logwood and sulphate of iron. Large quantities of crin végétal are exported from Algeria, chiefly to Germany, Italy, Austria-Hungary and France. The black kind is used by upholsterers as a substitute for horse-hair.

Total Exports of Vegetable Curled Hair from Algeria

Year.	Quantity. *Tons.*	Value. £
1911 . . .	46,426	212,320
1912 . . .	54,686	296,520
1913 . . .	58,509	332,960

Exports from Algeria to the United Kingdom

Year.	Quantity. *Tons.*	Value. £
1911 . . .	1,670	7,640
1912 . . .	1,696	8,960
1913 . . .	3,441	19,600

Algerian curled hair is usually quoted in the London market at the following prices: green, £5–£6 per ton; black, £9 per ton.

Raffia or Bass

This product is the well-known material which is used by gardeners for tying up plants, and is also employed for the manufacture of matting. It is obtained by peeling off the cuticle from the leaves of various species of Raphia palms, and consists of a thin fibrous substance which is divided, by means of a kind of comb, into strips or ribbons of the width desired for the purpose for which it is intended. It is chiefly supplied from Madagascar where it is derived from *Raphia Ruffia*. The product usually comes on the market in straw-coloured or pale yellowish-brown strips varying from $\frac{1}{4}$ inch to $\frac{3}{8}$ inch in width and from 3 to 4 feet long. Small quantities of coarser kinds of raffia are exported from West Africa where they are obtained from other species of Raphia, especially *R. vinifera*.

Exports of Raffia from Madagascar

Year.	Quantity. *Tons.*	Value. £
1911 . . .	6,256	137,543
1912 . . .	6,991	151,517
1913 . . .	5,961	137,048

The exports of raffia from Madagascar to the United Kingdom in 1913 amounted to 330 tons, of value £8,491.

The value of the material varies with the quality; it is usually quoted in the London market at prices ranging from £25 to £35 per ton.

Paper-making Materials

No account of vegetable fibres would be complete without some reference to the numerous materials used for paper-making. Within the limits of the present work, however, it is only possible to draw attention to some of the principal products used for this purpose, leaving any reader who may be particularly interested in this branch of the subject to consult the special text-books on paper-making.

The supporting tissue of all the higher plants is composed of fibrous elements which, when isolated from the softer, cellular tissues, can be reduced to a pulp capable of being used, either alone or in admixture, for the manufacture of paper. The practical application of these products on a commercial scale, however, depends on several factors, such as the supply of the raw material, the cost of collecting and converting it into pulp, and the quality of the product, including the length, strength and felting capacity of the fibres, and the colour of the pulp and the ease with which it can be bleached.

The chief fibres at present employed in the paper industry are cotton, flax, hemp, jute, Manila hemp and other cordage fibres, wood pulp, esparto, and straw.

In the case of cotton, the raw material consists mainly of rags and waste from the spinning mills; during recent years the " fuzz " or short fibre on the husk of the cotton seed has also been employed. Flax is used in the form of linen rags, spinning waste, and scutching refuse. The hemp employed consists similarly of spinning waste, scutching refuse and old cordage. Ramie waste is sometimes used for special kinds of paper to which it imparts considerable tenacity. Jute waste of several kinds is used, such as the butts or root-ends (page 138), waste from the textile factories, and old sacking. Manila hemp and other rope-making fibres (such as Sisal hemp and New Zealand hemp) reach the paper-mills chiefly in the form of old ropes; these are disintegrated by machinery and treated with caustic soda or lime. Manila hemp furnishes strong, tough papers.

Wood Pulp.—Enormous quantities of wood are now employed for conversion into wood pulp for paper-making. The soft, coniferous woods, such as the various kinds of fir, pine and spruce are used in Scandinavia and Canada, whilst poplar and timber of certain other dicotyledonous trees are employed in the United States and certain parts of Europe.

Wood pulp is of two kinds, mechanical and chemical. In the manufacture of mechanical wood pulp, the trees after being felled are sawn into blocks about 2 feet long. The bark is then removed and the wood is ground by forcing the blocks by hydraulic pressure against rapidly revolving grindstones over which a continuous stream of water is caused to run. The ground wood is carried by the water into a pit below the grinder and the coarser pieces are removed by passing it through a series of strainers. The pulp is then submitted to pressure to expel the water, and is subsequently converted into sheets by passing it between rollers. It is usually packed for export in the moist state, as if it is kept dry for any considerable time it loses its felting power.

The process of preparing chemical wood pulp consists essentially of the digestion of the chipped wood with a chemical solution under pressure at a high temperature. In the "sulphite" process of manufacture, the liquor employed consists of an aqueous solution of bisulphite of lime or magnesia, prepared by passing sulphur dioxide (sulphurous acid gas), produced by burning sulphur or pyrites, up towers packed with lumps of limestone or dolomite through which water is trickling. In the "soda" process, the wood is digested with an aqueous solution of caustic soda, and in the "sulphate" process, a solution of sodium sulphate and caustic soda is employed.

Whilst mechanical wood pulp consists merely of ground wood and contains all the encrusting substances of the fibres, chemical wood pulp is composed of the fibres which have been freed from the resinous and gummy matters by the action of chemicals. Chemical wood pulp is therefore of much better quality than that produced by the mechanical method and realises considerably higher prices. It is mostly exported in the dry state, as the loss of felting power which takes place with mechanical pulp does not occur in the case of this product.

The total imports of wood pulp into the United Kingdom during the years 1911–15 were as follows :

Year.	Quantity. *Tons.*	Value. £
1911 . . .	784,296	3,743,445
1912 . . .	925,590	4,418,420
1913 . . .	977,757	4,617,739.
1914 . . .	990,272	4,888,170
1915 . . .	954,050	5,314,245

The quantity and value of the different kinds of wood pulp imported into the United Kingdom in 1914 and the countries of origin are shown in the following tables.

Mechanical Wood Pulp

DRY.

	Tons.	£
Russia	1,308	6,289
Sweden	3,914	19,799
Norway	211	1,074
Other Countries	192	1,152
Total	5,625	28,314

WET.

	Tons.	£
Russia	200	410
Sweden	108,948	248,814
Norway	280,178	635,172
Canada	110,331	259,702
Newfoundland	51,751	129,380
Total	551,408	1,273,478

Chemical Wood Pulp, Dry

BLEACHED.

	Tons.	£
Russia	272	2,870
Sweden	5,071	51,027
Norway	11,053	129,610
Germany	803	8,255
Austria-Hungary	106	1,133
United States	1,114	12,296
Other Countries	262	2,852
Total	18,681	208,043

UNBLEACHED.

	Tons.	£
Russia	31,893	261,810
Sweden	282,898	2,350,093
Norway	51,500	455,681
Germany	24,798	202,585
Portugal	1,144	9,521
Austria-Hungary	2,007	15,332
Other Countries	2,159	19,417
Total	396,399	3,314,439

Chemical Wood Pulp, Wet

	Tons.	£
Sweden . . .	10,347	37,318
Norway . . .	5,054	15,340
Other Countries .	2,758	11,238
Total . .	18,159	63,896

The relative value of the different kinds of wood pulp is shown by the following prices which were quoted in the London market in July, 1914:

Mechanical Wood Pulp:

Dry, £4–£4 5*s*. per ton.

Wet, £1 19*s*. 6*d*.–£2 per ton.

Chemical Wood Pulp:

Sulphite, bleached, £11 15*s*.–£12 5*s*. per ton.

Sulphite, unbleached, £7 10*s*.–£8 12*s*. 6*d*. per ton.

Soda, unbleached, £6 17*s*. 6*d*.–£7 15*s*. per ton.

Esparto.—This product is a grass, *Stipa tenacissima*, which grows wild over large areas in Spain, and in Algeria and other parts of North Africa. It flourishes on sandy, ferruginous soils in dry, sunny situations on the coast. The plants attain a height of 3 or 4 feet, and have cylindrical, wiry stem-like leaves coated with short hairs; they usually grow in patches varying from 1 to 3 feet in diameter. The leaves are gathered during the dry, summer weather by grasping them with the hand and exerting a firm, steady pull. They are tied into bundles and packed tightly in bales by hydraulic pressure.

Esparto is converted into a pulp for paper-making by heating it with solution of caustic soda under pressure. The average yield of dry pulp is about 45 per cent. of the weight of the raw material. The ultimate fibres of which the pulp is composed vary in length from 0·5 to 3 mm. (0·02–0·12 inch) and have a fairly uniform diameter of average about 0·012 mm. (0·0005 inch).

The approximate quantity and value of the esparto imported into the United Kingdom during 1910–1915 were as follows:

	Quantity. *Tons.*	Value. £
1910 . . .	193,218	666,136
1911 . . .	201,636	671,999
1912 . . .	198,713	692,264
1913 . . .	204,957	743,354
1914 . . .	183,144	728,470
1915 . . .	137,538	660,569

The sources of the imports in 1914 are shown below.

From	Quantity *Tons.*	Value. £
Algeria . . .	81,780	295,058
Spain . . .	37,263	194,096
Tripoli . . .	7,661	28,074
Tunis . . .	56,212	210,287
Other Countries .	228	955
Total . .	183,144	728,470

The prices of esparto and esparto pulp in the London market in July, 1914, were as follows:

Esparto, Spanish, £5–£5 10*s.* per ton.

Esparto, North African, £3 10*s.*–£4 2*s.* 6*d.* per ton.

Esparto pulp, bleached, £15–£19 per ton.

Straw.—Large quantities of straw pulp, made by heating straw with caustic soda solution under pressure, are imported into the United Kingdom chiefly for the manufacture of brown papers and straw boards. The straws of wheat, barley, oats and rye are those most commonly used for this purpose, and give yields of pulp varying from 40 to 45 per cent. Straw pulps were quoted in London in July, 1914, at £12–£13 per ton.

Bamboo.—The Chinese have long employed bamboo for making their native paper, but its use in modern paper-mills has been retarded owing to the severe treatment which was found necessary to disintegrate the nodes of the mature canes. This difficulty has now been surmounted, however, by crushing the canes and treating them with hot water before submitting them to the action of chemicals in the digester. Factories in which bamboo constitutes the raw material have been established in Formosa and Indo-China, and the erection of factories in India is at present under contemplation.

Bagasse or Megasse.—A good deal of attention has been devoted to the fibrous residue of the sugar factories, which is left after the removal of the juice from the sugar-cane and is known as "bagasse" or "megasse." This product has been employed in paper-mills in Trinidad and Cuba, and its use seems likely to extend.

Baobab Bark.—The "Baobab" or "Monkey Bread" tree (*Adansonia digitata*) is extremely abundant in West Africa. The inner bark of this tree is very fibrous and is said to possess properties which render it of exceptional value for the manufacture of strong, light-coloured wrapping paper with a high finish. In order to prepare the material for the market, the hard outer bark is first removed by chopping and the inner bark is then stripped off in large sheets. It is used by the natives for making ropes and sacking. Small quantities are exported to the United Kingdom from West Africa, and realise prices of about £4 10*s*. to £6 per ton in Liverpool. The ultimate fibres of this material vary in length from 0·14 to 0·21 inch, with an average of 0·18 inch.

Other Materials.—Among other materials which have been employed commercially, mention may be made of peat which has been used to some extent in the manufacture of cheap brown paper, and the paper mulberry (*Broussonetia papyrifera*) which is employed in China, Japan and Burma, and yields a very strong paper.

A number of other fibrous materials have been investigated at the Imperial Institute, and found to be capable of being converted into satisfactory pulp for paper-making. An account of these will be found in *Selected Reports of the Imperial Institute, Part I, Fibres*, and in the *Bulletin of the Imperial Institute* (1912, X, 372; 1913, XI, 68; 1914, XII, 42; and 1916, XIV, 163). Among the more promising of these are the papyrus of the Sudan and East Africa Protectorate, "Elephant grass" (*Pennisetum purpureum*) of Uganda, and the "Spanish reed" (*Arundo Donax*) and "Tambookie grass" (*Cymbopogon Nardus* var. *vallidus*) of the Transvaal.

In the *Kew Bulletin* (1912, No. 9) attention has been drawn to the suitability for paper-making of *Hedychium coronarium*, of the natural order Zingiberaceæ, a plant which is indigenous to India and also occurs in Central America, the West Indies, New Zealand, West Africa, and Brazil. Reference is made in the same issue to two other plants of the Zingiberaceæ, viz. *Amomum hemisphericum* and *Alpinia nutans*, and also to the "Marram" grass which commonly grows on the sand-hills of the coasts of the United Kingdom.

All these plants yield satisfactory pulps which would be quite serviceable for paper-making.

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