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HAWAII AGRICULTURAL EXPERIMENT STATION.

J. G. SMITH, SPECIAL AGENT IN CHARGE.

BULLETIN No. 16.

THE CEARA RUBBER TREE IN HAWAII.

BY

JARED G. SMITH,

SPECIAL AGENT IN CHARGE OF HAWAII AGRICULTURAL EXPERIMENT STATION,

AND

Q. Q. BRADFORD,

ASSISTANT IN RUBBER INVESTIGATIONS.

UNDER THE SUPERVISION OF

OFFICE OF EXPERIMENT STATIONS,

U. S. DEPARTMENT OF AGRICULTURE.

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HAWAII AGRICULTURAL EXPERIMENT STATION, HONOLULU.

[Under the supervision of A. C. TRUE, Director of the Office of Experiment Stations, United States Department of Agriculture.]

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LETTER OF TRANSMITTAL.

HONOLULU, HAWAII, *March 10, 1908.*

SIR: I have the honor to transmit herewith, and recommend for publication as Bulletin No. 16 of this station, a paper on the Ceara Rubber Tree in Hawaii, prepared by myself, assisted by Mr. Q. Q. Bradford. The paper embodies the results of one year's experiments in tapping rubber trees. It is believed that the methods and apparatus devised represent a distinct advance toward the successful solution of the problem of commercial tapping of trees of this variety for the production of rubber.

Respectfully,

JARED G. SMITH,
Special Agent in Charge.

DR. A. C. TRUE,
Director Office of Experiment Stations,
U. S. Department of Agriculture, Washington, D. C.

Recommended for publication.
A. C. TRUE,
Director.

Publication authorized.
JAMES WILSON,
Secretary of Agriculture.

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THE CEARA RUBBER TREE IN HAWAII.

INTRODUCTION.

The natural home of the Ceara rubber tree (*Manihot glaziovii*) is in the dry regions of Brazil. In former years it was very abundant in the State of Ceara and derives its name from this fact. It is also known as the Manicoba rubber, this having been its native name.

BOTANICAL RELATIONSHIPS.

This tree is closely related to the cassava (*Manihot utilissima*). It belongs to the spurge family, which also includes the Para rubber (*Hevea brasiliensis*) and many other rubber-producing plants. Most of the members of this group, the Euphorbiaceæ, have milky sap.

HABIT OF GROWTH.

The Ceara rubber is a rapidly growing tree with a loose, spreading, and not very leafy top. It usually branches in threes and these again branch in turn, and so on during the life of the tree. The leaves are long-petioled, simple, peltate, deeply three to seven palmately parted, the uppermost leaves entire; the lobes are entire, broad, ovate-lance-shaped. When growing in the open, under favorable conditions, the trunks of the Koloa grove of trees, 14 years old, average about 44 inches in circumference at 3 feet from the ground. In a natural forest the trees begin to branch from near the ground to 20 feet or more above. The wood is soft and spongy, and the growth rings are not prominent.

THE ROOT SYSTEM.

The roots (Pl. I) are shallow and are not very numerous. They are thick and fleshy and bear elongated, fleshy tubers, very much resembling the roots of the cassava and sweet potato. The young tubers have a very thin bark and contain a large percentage of starch. As the tubers grow older the bark thickens, the outer surface becomes woody, and the center is filled with pith, saturated with water.

THE LATEX SYSTEM.

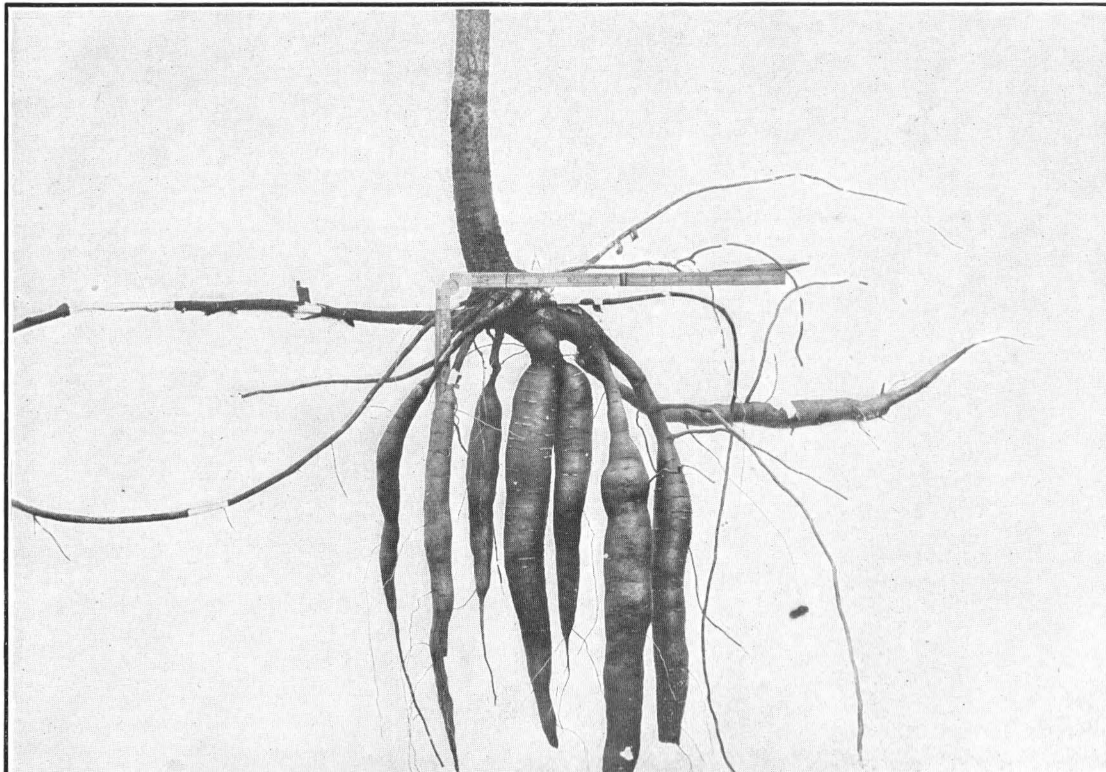
The latex occurs in the leaves and leaf petioles and in the bark of the twigs, trunk, and roots. The wood contains no latex, although there are latex tubes in the pith. There is a continuous network of milk tubes all through the living, green portion of the bark of the trees.

The innermost portion of the bark of all dicotyledonous trees is the portion from which growth proceeds, and is called the "cambium" layer. On the inner side of the cambium wood cells are produced, but growth outward produces the tissues known as bark. Growth in diameter is by accretion of wood in a continuous layer around the whole circumference of the trunk on the inner side of the cambium. There are no milk tubes in the cambium. The cambium being the most vital portion of the tree, the greatest care must always be exercised to prevent cutting too deep and injuring this layer of tissues.

The latex, or milky sap, of the rubber tree is of very complex composition, containing starch, sugars, gums, resins, proteids, and salts, as well as rubber. The milk tubes are not continuous—that is, it is not possible by cutting through the network of tubes at the base of the tree to drain out all of the latex. The latex-bearing tissues may rather be compared to a series of short tubes joined end to end with permeable diaphragms between. In the living plant there is free transfer of latex from one tube to another, but there is no circulation comparable with the circulation of the blood in animals. There is no rise and fall of the sap, as is the common belief, and so far as has been determined, there is no ruling direction of movement at any time of the day or period during the growth of the plant. The circulation of the sap in the tree or of latex in the milk tubes is simply a process of life, a phenomenon of growth.

The rubber in the latex in the milk tubes is supposed to exist as an emulsion, somewhat comparable to fat globules in milk. When a milk tube is ruptured, to permit its contents to escape, the rubber globules rapidly agglutinate, the function of rubber apparently being to close up wounds and prevent the loss of water from the tree by evaporation.

The flow of latex when the milk tube is ruptured is not due to the continuity of the tubes, as would be supposed, but is because the latex is under tension in the growing trees. When the pressure is relieved by the breaking or cutting through of the tissues containing the latex, the tension being released, the milk tubes for a short radius around the wounds quickly empty themselves of their contents.



Tuberous Roots of a Six-Months-Old Ceara Rubber Tree.

THE SEED.

One of the characteristics of the Ceara rubber tree is that it sheds its leaves in the spring of the year. After a rest of from one week to two months new leaves are put forth and growth is renewed. The flowers are produced in the early part of the summer. These are greenish yellow, with a very abundant supply of nectar. The seeds are borne three together in a round capsule about an inch in diameter. When the seeds ripen the capsule (Pl. II, fig. 2) dries and explodes, throwing the seeds often 10 or 15 yards from the mother tree. The seed is shaped somewhat like a plum pit, about 0.5 inch long, mottled grayish brown, smooth, and shiny. The seed coats are hard and stony. The seed retains its vitality for two or three years or more, and is apparently more readily germinated when at least six months old than when fresh from the tree.

THE SEED BED.

Considerable care is needed in the selection and preparation of the ground for a nursery. It should be placed in a warm, sunny location, well protected from the winds, and, in the drier portions of the islands, with a near-by water supply. Two methods of starting the seeds are in vogue. Either sow the seed in nursery rows in the ground or plant them in flats, or shallow boxes filled with loose, mellow earth. The same care is necessary in selecting the earth for either seed boxes or nursery plantings as in the case of any other forest tree seedlings. An arrangement of partial shade, either by coverings of slats or cloth, is highly desirable.

SEED-BED ENEMIES.

The most serious enemies of seedlings, apparently rather common in Hawaiian soils, are the nematode worms. It has been found that the very large losses of seed in the seed beds have been due in many instances to the ravages of this microscopic worm instead of to the lack of vitality of the seeds.

There is no known cultural remedy for nematode worms where they affect cultivated crops. In a nursery, however, where the amount of soil used is comparatively small, it is entirely practicable to prevent infection by sterilizing the soil, as is recommended for the tobacco seed bed.[a] This is best accomplished by the use of live steam. The soil should be cooked for an hour or more—long enough to kill all larvæ, eggs, and adults not only of nematodes but of all injurious insects in the soil. Sterilization of the soils used in nur-

[a] Hawaii Sta. Bul. 15.

series will also prevent, in a large measure, losses from the damping-off fungus, molds, and other fungi.

PREPARATION OF THE SEED.

The natural germination of the Ceara rubber seed requires about a year because of the very thick, hard, waterproof seed coats (Pl. II, fig. 1). To hasten germination various methods of treatment are employed. Probably the best of these is to file the edges. The best place to file the seed is where it is flattened at the base, directly over the plumule. Care should be taken not to file too deeply so as to injure the plumule. Another method is to pour boiling water on the seeds and allow them to soak for twenty-four hours. Another is to soak the seeds in water and then germinate in the bottom of a "sun box," a shallow box painted black on the inside and covered over with a sheet of glass. Still another method is to place the seeds in shallow soil over hotbeds filled with fresh stable manure. This method is undesirable because of the liability to infection from molds and the damping-off fungus often present in fresh manure.

Seeds from 6 to 18 months old usually germinate better than seeds fresh from the tree. Heavy losses in the seed beds occur through the depredations of rats and mice, which are very fond of these seeds. Ants, too, are very injurious. Rats may be poisoned or trapped, or the seed beds may be protected from their incursions. The best method of getting rid of ants is to put the seed boxes on posts protected with ant poison. It is also well to destroy the ant nests with boiling water or carbon bisulphid.

TRANSPLANTING TO POTS.

A week after the seeds have germinated the young plants should be transplanted into pots. A convenient form of pot for transplanting rubber seedlings or, for that matter, any other tree seedlings is one made of ti leaves formed over the bottom of a quart bottle and tied with string or fiber, taking two leaves to make the pot. Pots may be cheaply made of heavy manila paper dipped in hot paraffin, paper alone being too easily torn when wet. A joint of bamboo filled with earth makes an excellent pot. Using either of these styles, the plant is set out in the field in the pot at the time of transplanting, and there is no marked retardation of growth, as often follows when the plants are dug from nursery rows.

TRANSPLANTING TO THE FIELD.

Before the seedlings are taken to the field the ground must be prepared for them. In the Nahiku and other wet districts the land is first cleared of standing timber and underbrush and the fern stumps

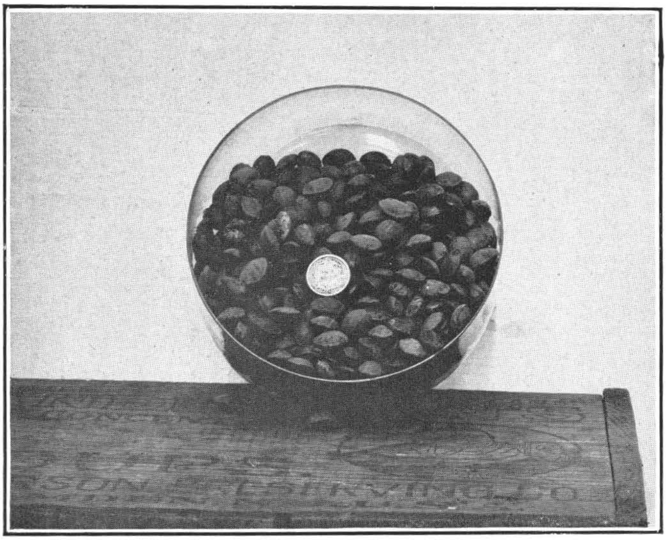


FIG. 1.—CEARA RUBBER SEED.

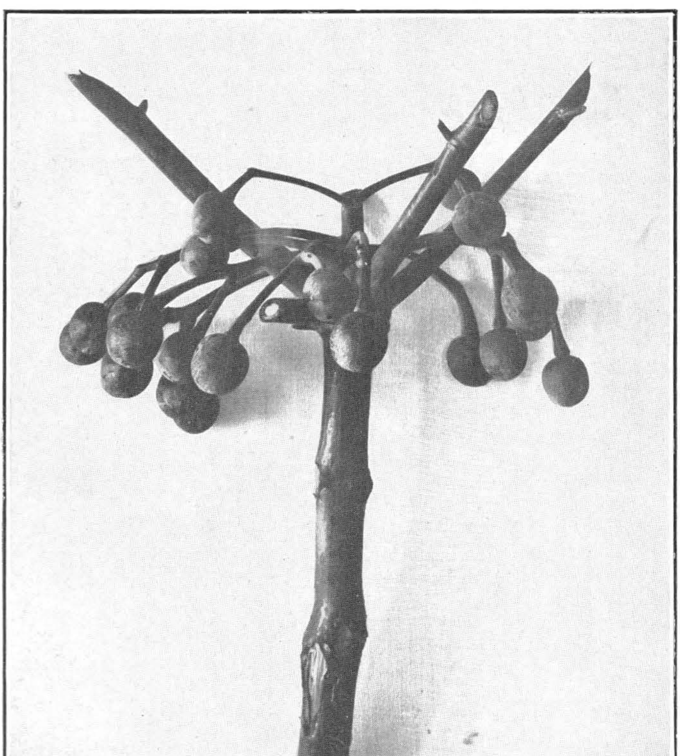


FIG. 2.—SEED CAPSULES OF THE CEARA RUBBER TREE.

are cut and piled. In the drier locations in Kona, Puna, or Koloa, in Kauai, or any other leeward districts of the islands, the lantana and guava are cleared and burned and, if free from rock, the land should be plowed. Plowing, however, is not practicable in many of the districts where the cultivation of rubber has been undertaken. Where the land can not be plowed holes are dug at proper distances. The holes should be at least 2 feet across and as deep as practicable. If the soil is porous the hole or circle of cleared ground in which the tree is to be planted can be most cheaply prepared with a hoe or mattock. In the heavier soils a good method is to blast, using giant powder. A 1¼-inch octagon steel, sharp-pointed drill is driven down about 2 feet and one-third of a stick of No. 2 giant powder with fuse cut just long enough to reach above the surface, is dropped into the hole; no tamping is required. Blasting is cheaper than digging where the soil is close and dense, and this method has the further advantage that the land can be very quickly prepared, two men making from 150 to 225 holes a day. When blasted, the land is left in better condition than where a hole is dug with pick and shovel, as the subsoil is opened up and cracked, allowing the roots to penetrate. This method also improves the drainage.

WHEN TO TRANSPLANT.

The best time to plant the Ceara rubber tree is in the spring, from January until March, following the rule which applies to all agricultural crops, that those seedlings which receive the benefit of hot, growing weather make a better and more healthy growth than those planted at the end of the growing season. If in pots, these should be watered before transplanting. A good time to transplant is in the evening or late afternoon, or on cloudy days, so that the plant may become accustomed to its new location without excessive wilting. Even if the seedling is in a ti leaf or paper pot there is more or less disturbance of its roots when transplanted.

DISTANCES FOR PLANTING.

There is considerable variation in the distances of planting adopted on rubber plantations. One method is to plant in a double row, 5 by 15 feet. Other plantings range from 10 by 10 feet to 20 by 20 feet. The object of planting close would be to have the plants more quickly shade the ground and economize on cultivation, through the shading of weed growth. However, as the tree will not reach a sufficient height to shade the ground short of three years, other things should be considered. The proper distance of planting will have to be worked out in each of the districts of the islands, and will depend as much upon the ability of the soil to grow the trees as on the habit of growth of the tree itself. Another advantage of close planting is that in three to five years, when tapping begins, trees of poor growth or individuals poor in rubber, or those that are diseased or unhealthy, can be cut out and destroyed, and there will still be enough left for plantation purposes.

CULTIVATION.

The rubber planters in Hawaii have thus far confined themselves to the growing of rubber as the sole agricultural crop. It is a question whether this is the best policy on account of the time required for the trees to attain the proper size for tapping and because of the expense of maintenance through these early unproductive years. It is believed that better results can be obtained through growing some annual or biennial crop to yield an immediate revenue. The advantages would be cultivation of the trees as a secondary crop only, saving expenses, and obtaining a better and more rapid growth of the rubber trees through the cultivation of the land between them.

The cultivation of plantations already in existence in Hawaii has in the main been limited to clearing the weeds from a circle around the trees. In some instances where the growth is excessive the weeds have been mowed and used as a mulch around the base of the trees. The mulching of rubber trees is highly recommended for the Kona districts, especially if the mulch is covered with earth. On only one plantation has there been any attempt to adopt clean cultivation. It is believed that pineapples, tobacco, soja beans, bananas, cassava, cotton, and garden vegetables are crops which may be profitably grown in rubber plantations. Any one of these will yield returns more quickly than rubber, and all are on a basis of profitable cultivation. Such catch crops can be cultivated for two or three years, not only without detriment to the roots of the rubber trees, but to the very decided advantage of this final crop, through the loosening up and stirring of the soil.

FERTILIZERS AND CATCH CROPS.

If catch crops are grown in a rubber plantation the commercial fertilizers used should be of low grade, containing little more than enough nitrogen to satisfy the needs of the catch crop, and potash and phosphoric acid in such forms as will become gradually available during the period of several years after the catch crop is disposed of.

While this station has undertaken a number of pot experiments to determine the value of fertilizers as applied to rubber, only an indication of the fertilizer requirements has thus far been obtained. The Nahiku soils require lime and potash. The lime should be applied at a rate of not over 200 pounds per acre. The potash should

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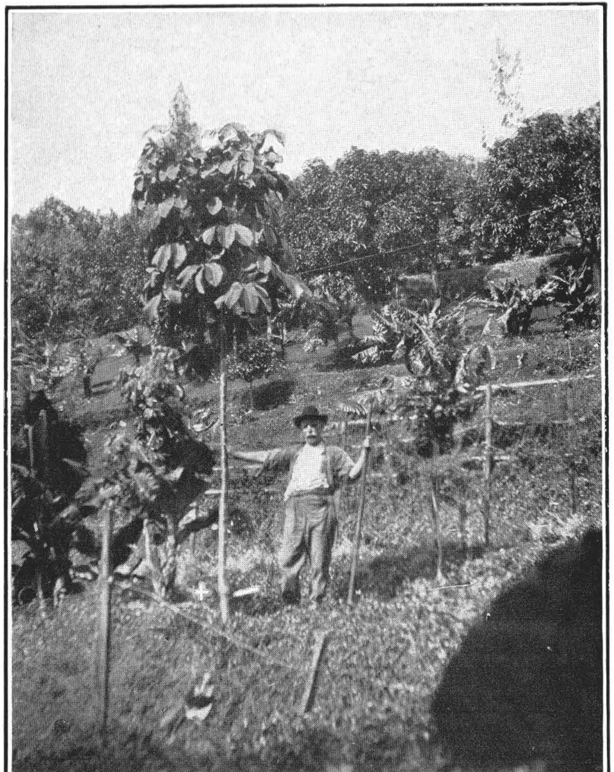

FIG. 1.—SUCKER NINE MONTHS OLD, THE MARKS (+, —) SHOWING POINT, NEAR THE GROUND, AT WHICH THE TREE WAS CUT OFF.

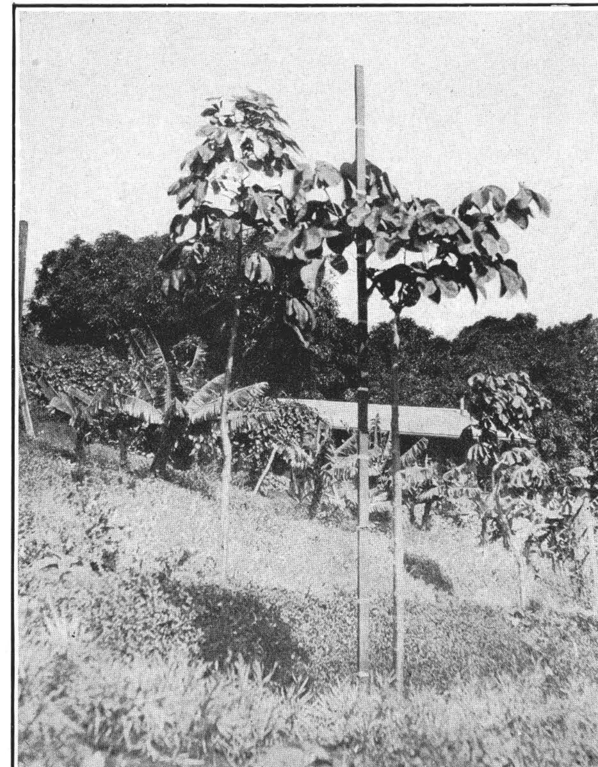

FIG. 2.—THE TOP CUT FROM THE ROOT OF THE TREE SHOWN IN FIG. 1, PLANTED AS A CUTTING, THIRTEEN MONTHS' GROWTH.

TWO RUBBER TREES FROM ONE SEED.

be in the form of either sulphate or of double magnesium salt, and should be applied immediately around the tree.

While rubber cultivation is a new industry in Hawaii and conclusive work has not as yet been done, the probabilities are that the highest yield of rubber per tree or per acre will be obtained from trees which have made the most rapid and vigorous growth, and every effort should be made to promote this end. The Ceara rubber is a plant new to cultivation, but it is probably safe to say that it will respond as readily to scientific methods as have other wild plants.

PRUNING.

Very little work has been done with pruning rubber trees in Hawaii. Enough, however, is known to indicate that it is advisable to force the tree to produce a straight, unbranched trunk not more than 10 feet in height. If the tree shows a tendency to grow 15 to 20 feet without branching it should be forced to branch at from 7 to 10 feet from the ground by cutting off the terminal buds of the main trunk, and again cutting back the main shoots as they appear, until two or more branches are formed. Trees that branch near the ground, or under 7 to 10 feet in height, should have all but one of the branches pruned off, and this operation should be repeated if the tree shows any tendency to again branch below that height. The pruning should be done just as soon as the branches are put forth. If the branch is allowed to become large before being cut off, the tree will make a crooked trunk, which will be difficult to tap later on.

PROPAGATION BY CUTTINGS.

The Ceara rubber tree is very readily propagated by cuttings. The best cuttings are taken from young trees, as they are not so likely to branch (Pl. III). Cuttings taken from eight to ten year old trees, especially trunks or branches of considerable diameter, show a great tendency toward branching at once. Even limbs that are broken from the tree or trees that have been overturned by storms will grow if cut in 2 or 3 foot sections and placed in the ground for about two-thirds of their length. A number of instances are on record where Ceara trees used for fence posts have taken root and continued growth. Seedlings six months or a year old may be cut near the ground, the trunk cut in two or more pieces, and set out in the field. These will root and throw up new suckers, which often make larger and better trees than the original.

ROGUING THE PLANTATION.

No two rubber trees are alike. For this reason every tree in the plantation should be tested before it is two years old to determine whether it yields a paying quantity of latex. There is no need of waiting four or five years to cut out unproductive trees. The widest variation exists both in the proportion of rubber contained in the latex and in the amount and freedom of flow of the latex itself. The outward appearance of the tree is no indication of its value as a rubber producer. The latex of some trees is thin and watery. The older the tree the thicker the latex, but there is great difference even among young trees. Trees yielding thin, watery latex without any appreciable amount of rubber should be cut out and destroyed and their places filled with cuttings taken from trees yielding large quantities of rubber. The value of the plantation can be rapidly increased by vigorously pursuing this policy.

SYSTEMS OF TAPPING.

A striking characteristic of the Ceara rubber tree is that it sheds its bark at frequent intervals. The outer bark is tough and papery. As new growth of bark forms immediately outside of the cambium layer, the outer bark dries and sloughs off. This process is continuous.

Before beginning tapping the entire outer bark should be removed from the trunk without injuring the living inner bark. This is easily done with a curved-blade knife shaped like a pruning hook, making one vertical cut and peeling off the bark in rings.

There are four systems generally employed in tapping the Ceara and other rubber trees in rubber-producing countries. These are the half herringbone, the full herringbone, the spiral, and the vertical cut systems. The half herringbone consists of a single vertical cut with laterals about a foot apart at an oblique angle extending half around the tree. The full herringbone consists of a vertical cut with oblique laterals on both sides extending entirely around the trunk of the tree. The spiral is a single or double oblique cut extending from the bottom to the top of the tapping area without vertical channels. In the vertical system there are from one to half a dozen vertical cuts without oblique laterals.

The Ceara rubber tree differs from both the Castilloa and Hevea in the rapidity of the coagulation of the latex. For this reason it has been found that the system of vertical cuts is the best. The station has carried on a large number of experiments in methods of tapping. It has been found that the average Ceara tree stops its flow of latex by complete coagulation within from two to five minutes when the latex is permitted to flow in the wound without the use of water. By trickling water over the wound the period of flow may be extended several minutes, but if the water is rendered alkaline with ammonia the period of flow is extended sometimes from thirty to forty minutes.

It has also been quite definitely determined that a system of single or double vertical cuts, from 3 to 6 inches apart, without any oblique laterals except at the base, for the purpose of concentration of all the latex at one point, gives the heaviest yield of rubber and the least waste. A vertical cut is much more easily made than either the spiral, half herringbone, or full herringbone oblique cuts. Another point in favor of the vertical cut is that the wound thus formed heals with the greatest rapidity.

The first cut should be extremely shallow. The cut should be flat, with sharp sides one-eighth of an inch wide and, if practicable, not more than one thirty-second of an inch in depth—the thinnest possible shaving. It is especially important in young trees not to cut too deeply, because the bark is very thin and there is great danger of permanently injuring the tree by cutting through to the cambium. The second tapping should be in the same cut without widening it. The next cut and the cuts of each succeeding day, as long as the tapping period lasts, should be to simply freshen the wound at one side only of the vertical incision. In this way the tapped area will be extended gradually in one direction around the trunk and will be followed by rapid healing of the wound from the opposite margin of the cut. The number of vertical cuts will depend on the diameter of the trunk. They should be not less than 4 or 5 inches apart, because the daily tappings drain the latex from the bark for from 1 to 2 inches in every direction from the wound. Enough uninjured bark must be left between the wounds to admit of rapid recovery and not too seriously interfere with the vital processes of growth.

TIME TO TAP.

The best time to tap Ceara rubber trees is at night or during the early morning. If tapping is done during the day it should be on the shady side of the tree. The reason for this is because of the tension of sap and latex in the body of the tree. Evaporation of water from the leaves is most rapid during the daytime. The greatest activity in pumping up water from the soil is also in the day. Under the action of direct sunlight the leaves accumulate great quantities of starch and sugars. At night there is a transfer of carbohydrates in soluble form from the leaves to those parts of the tree where growth and the formation of new tissues are taking place. During the hours of darkness there is an almost complete cessation of evaporation from the leaves, but the roots continue to take up water from the soil. This results in tension and explains the reason why the flow of latex is very much heavier and more rapid during the night. Coagulation is also retarded by the lower temperatures at night.

The best time to tap seems to be between 12 o'clock midnight and 7 o'clock in the morning. It is believed that some adaptation of the miner's lamp to be worn on the hats of the workmen will be necessary. If the tapping operation is postponed until earliest dawn it would largely increase the number of men required, owing to the few hours during which profitable tapping can be carried on.

The best season of the year for tapping has not been determined, but the indications are that it would be during the rainy season. In Hawaii the Ceara rubber trees can be tapped at any time of the year, but this operation should not be carried on during the resting period when the tree is bare.

APPARATUS AND METHOD OF TAPPING.

As a result of many trials, it was found that a cloth or canvas water bag was of great advantage in collecting the rubber (Pl. IV). A water bag large enough to hold about a quart of water, made with alternating narrow strips of thin porous cloth and oiled cloth or canvas, as shown (Pl. IV, fig. 2), is tied around the tree 6 or 7 feet above the ground, just above the tapping area. These bags are of cheap construction and will last for many months if properly cared for. A water bag should be fastened to each tree before tapping begins and should be left on the tree during the whole tapping season.

At the base of the tree the water and latex are collected in zinc, galvanized-iron, copper, aluminum, or enameled cups, or in wooden or earthen vessels. Iron vessels should not be used because of the corrosive action of the ammonia recommended for use in tapping. The water and latex are collected at one point at the base of the trunk by inserting a thin sheet of zinc obliquely beneath the outer bark. The channel and spout thus formed should not be fastened into the body of the tree because of injury to the wood. This tin or zinc collar and spout should be left on the tree during the whole tapping season.

The knife used should cut a shallow, flat channel with vertical margins and should be capable of delicate adjustment, because the bark of the Ceara rubber tree is very thin.

The preliminaries having been attended to, a water carrier goes through the grove, filling each of the bags with a pint of water containing ammonia at the rate of one-half ounce per gallon of water. The rubber contained in the latex of young trees coagulates more slowly than in old, so that in tapping a young grove a minimum amount of ammonia will be required. The water carrier should remove all scrap rubber from the tree, so that the wound will be clean and fresh for the tapper.

Immediately following the water carrier comes the tapper, who rapidly freshens the wound or cuts a new channel, as indicated above, and passes on to the next tree. As soon as all of the water has

PLATE IV.

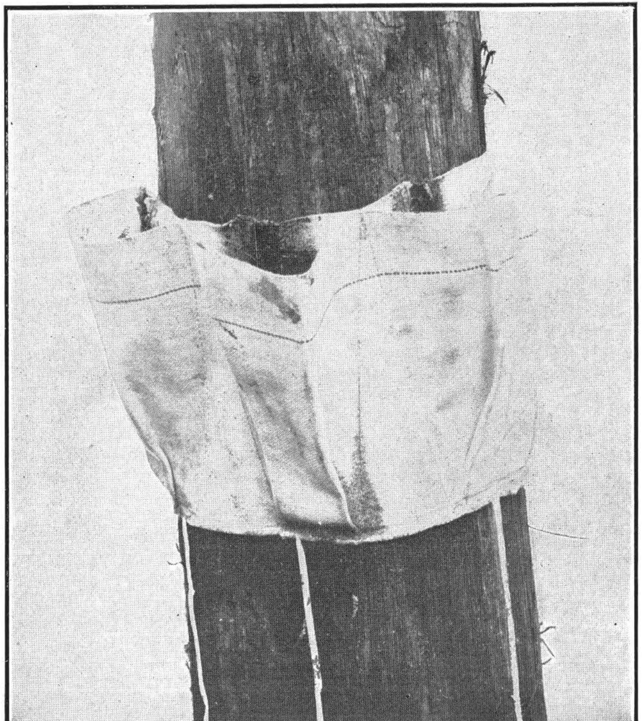

FIG. 1.—FRONT OF BAG, SHOWING WATER COMPARTMENTS, ONE FOR EACH VERTICAL CUT IN THE TAPPING AREA.

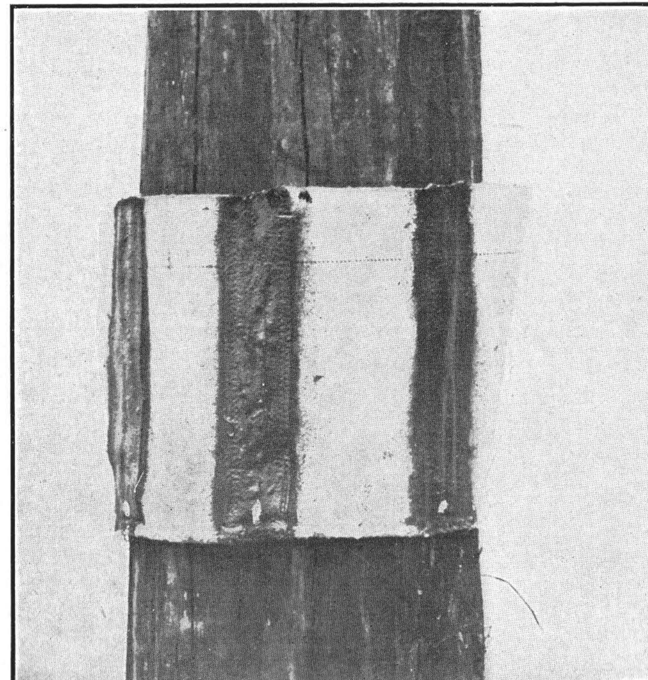

FIG. 2.—BACK OF BAG, MADE OF HEAVY CANVAS WITH THINNER CLOTH STRIPS OILED EXCEPT AT THE BASE OF EACH COMPARTMENT.

THE TAPPING BAG.

dripped out of the bags, collectors follow the tapping gang, emptying the containers into barrels or other receptacles for transportation to the coagulating house or central mill.

COAGULATION OF THE LATEX.

The first operation in coagulation is to strain the latex to remove particles of bark or earth or other large impurities.

A number of methods of coagulating latex are in use in rubber-producing countries. Among these are acetic acid, sulphuric acid, trichloracetic acid, common salt, alum, heat, evaporation, churning or agitation, and centrifugal force.

In the experiments which we have undertaken, as stated above, ammonia is added to the water which flows over the wound in the bark of the tree, made for the purpose of extracting the latex from the tree. The action of ammonia seems to be to retard coagulation. Latex containing moderate quantities of ammonia will remain without any appreciable coagulation for considerable periods, provided the mixture of water and latex is not violently churned, stirred, or shaken. In order to get rid of the ammonia, dilute sulphuric acid is added until the mixture shows a neutral reaction with litmus paper. The addition of sulphuric acid to a point of neutralization results in the formation of a small quantity of ammonium sulphate in the liquid. After standing for about one hour, a boiling concentrated solution of ammonium sulphate is poured into the neutralized latex and the whole is gently heated or is left standing. As the mixture is heated the rubber separates from the latex and water mixture and rises to the surface. The temperature of the liquid should not be permitted to go above 170° F., as the elasticity of the rubber is affected by high temperatures. The same results—that is, complete separation of the rubber from the water and latex mixture—can be obtained by allowing the latex to stand for a period of two to six hours after adding the ammonium sulphate solution, without heating, but the saving of time warrants the use of heat.

The rubber can also be coagulated by adding acetic acid without the use of heat. After adding the acid the mixture should be stirred or churned.

A very pure quality of rubber can be produced by the use of ammonium sulphate, because this salt precipitates the proteids, the proteids being compounds very liable to rapid decomposition. However, from the manufacturer's standpoint, it seems to be immaterial whether the rubber is free from proteids and other impurities.

Sulphuric acid is also a coagulant, but it should only be used in very dilute solutions.

Formalin may be used in conjunction with either ammonium sulphate, acetic acid, or sulphuric acid. When present in large excess, especially in the presence of ammonium sulphate, it has a rapid coagulating action. While the rubber produced by its use is of very high quality, the formalin preventing decomposition of the finished product, this compound is as yet too expensive for general plantation use.

Rubber may be obtained from the water and latex mixture without the use of ammonium sulphate by churning, by adding either acetic or sulphuric acid, with or without heat, or by simply allowing the liquid to stand until putrefaction begins.

One of the advantages of the collection of latex by means of water trickled over the wounds is the possibility of producing a product entirely free from bark, earth, twigs, and other gross impurities and adulterants. Where rubber has been collected from wild trees the common method has been to simply slash the trunk and branches, permitting the latex to flow down them or fall upon leaves placed on the ground beneath the tree. This method is a very wasteful one, and the rubber thus obtained is of uniformly low value because of the amount of dirt and other impurities. This method is not at all adapted to modern plantation conditions.

Every effort should be made to produce rubber of the purest and best quality; and it is believed that such rubber can best be produced from the Ceara tree by the use of considerable quantities of water in all of the processes connected with the collection and coagulation of the latex.

WASHING THE RUBBER.

As soon as all of the rubber has been separated from the latex it should be thoroughly washed in an abundant supply of fresh water. An important part of the washing process is to rub and knead the rubber. The tensile strength of the rubber is very much improved by thorough rubbing. For this rubbing and washing, either hand methods or machinery may be utilized.

After thoroughly washing and rubbing the rubber, it should be passed through a wringer to flatten the sheets and make them of uniform width and thickness.

DRYING THE RUBBER.

Two methods of drying are in vogue—by the use of vacuum pumps and low temperatures, or by placing the sheets of rubber on frames or shelves in drying houses so arranged that currents of dry air at low temperatures may be passed through the house. If a drying house is used, the rubber should be smoked during the drying process, but the temperature should not be allowed to go above 120° F. As soon as the rubber is dry to the touch, and has lost about 25 per cent of its weight, it is ready to pack for market.

BALING THE RUBBER.

There is the widest variation in the form of packages and in the method of putting up rubber for shipment to market. It can be prepared in the form of biscuits, pancakes, sheets, lace, crape, or in blocks. It must be so packed as to economize space in shipment by ocean freight. Great care is necessary to protect it from moisture, so that there will be no deterioration through decomposition at any point from the plantation to the manufacturer. Rubber molds very readily and if the packages in which it is packed for shipment contain too much moisture, putrefaction occurs, the rubber becomes "tacky," and its selling price is greatly reduced. Every effort must be made to prevent decomposition, by drying, smoking, or coating the outer surface of the package with an antiseptic.

TAPPING EXPERIMENTS ON KAUAI.

Two groves of Ceara rubber trees were discovered on the island of Kauai during the summer of 1906 by Mr. Charles F. Judd, a forest ranger in the employ of the Territorial board of commissioners of agriculture and forestry. One of these groves, at Koloa, was planted about 1894. The grove at Lihue was planted five years later with seeds taken from the trees at Koloa.

THE KOLOA GROVE.

The grove at Koloa contains about 90 trees, only about one-third of these being of the original planting, the others being volunteer seedlings. The grove is very scattering, covering 4 or 5 acres. These trees, having grown at wide intervals, are much branched, with broad, spreading tops. The trunk of the largest tree in this grove is 47 inches in circumference, at 3 feet from the ground.

The land on which the Koloa grove is situated is very rocky, lying at the foot of the lower slope of the crater of Kalohana. The rainfall is abundant, probably averaging 60 inches per annum. The slope is toward the southwest. The location is protected from trade winds by the mountain spur above it, so that while the soil is not of the best, the complete protection from winds and the southern exposure make this location favorable for the rapid growth of any species of forest tree.

THE LIHUE GROVE.

The grove at Lihue is situated in a swampy gulch and is surrounded on all sides by a dense forest of ironwood and koa. This grove is about 9 years old, having been planted in 1898 by a German forester in the employ of the Lihue Sugar Plantation. The trees are in rows about 12 feet apart and were originally at equal intervals in the row. They are very irregular in size, ranging from 12 to 42 inches in circumference at 3 feet from the ground. The trunks are mostly tall and slender, branching at from 3 to 25 feet. On account of the dense shade the branches are almost erect, very slender, leafy only at their extremities. The Lihue rubber trees are planted in an unsuitable location for this variety of tree. The ground is a bog at most seasons of the year. The ironwood forest, having made a more rapid and taller growth, has cut off the supply of sunlight from the rubber grove and the trees are in shade practically all of the time. There are about 110 trees in this group.

TAPPING THE LIHUE TREES.

Tapping experiments were begun at the Hawaii Experiment Station in Honolulu in December, 1906. This preliminary work was undertaken to find out something in regard to methods. Satisfactory preliminary methods having been worked out, a rubber-tapping experiment was undertaken at Lihue, Kauai, January 23, 1907.

After putting up a small house and getting tools, apparatus, and supplies together, tapping was commenced January 26, 1907. The method used was that of applying water containing ammonia to half-herringbone cuts in 3 trees. Using the water, the latex ran very freely for thirty minutes in 2 of the trees. In one of the trees the latex was yellow and hardly flowed at all. The amount of rubber obtained from this tree was very small and poor in quality.

On January 28 the trees were again tapped by freshening the old wounds. The tree with the yellow latex yielded no latex until the bark had been cut away for about an inch on each side of the original wound. At 2 inches from the original wound the latex flowed freely for three-quarters of an hour. The other two trees ran freely on freshening the old cuts. The latex from these two trees, after neutralizing with formalin, was divided into equal parts and allowed to stand for one hour. A boiling concentrated solution of ammonium sulphate was then added. Half of the liquid was boiled, the other half allowed to stand. The portion that was heated gave one-fourth of an ounce of dry rubber. The portion that was allowed to stand without heating yielded three-fourths of an ounce of dry rubber, much better in quality than that which had been heated.

On January 29 the same trees were again tapped by freshening the old wounds. The one with the yellow sap yielded very little latex—just enough to slightly color the water which was trickled over the wound. The other two trees continued to flow for one hour. The latex was then gathered, strained, and neutralized by adding 2 ounces of formalin per gallon of the mixture. It was then allowed to stand one and one-half hours. The filtrate of ammonium sulphate and latex, which had been used in the preceding coagulation, on January 28, was poured into this while hot. After standing for thirty minutes the rubber was skimmed off the liquid. The result of this day's tapping was 1 ounce of pure rubber. The remaining liquid was divided into equal parts. One of these was heated and the other allowed to stand for three hours. The portion which was allowed to stand without heating yielded a second "cream" of rubber about the size of a sparrow's egg. That which was heated yielded a second cream of about three times as much. It took fully three hours to secure all of the rubber from the latex mixture.

On January 30 the same three trees were tapped by freshening the old wounds. The latex flowed about thirty minutes. The filtrate from the solution used on the previous day was strained through cloth and was poured into the fresh latex while hot. The latex was not otherwise acidified. In this day's tapping only one-fourth ounce of ammonia per gallon of water was used on the trees. This was markedly alkaline. The filtrate from the previous day showed an acid reaction. The latex mixture was left standing one hour and the rubber skimmed off, obtaining one-half ounce of pure rubber. A concentrated solution of 1 ounce of ammonium sulphate in water heated to boiling was then poured into the whole filtrate of about 2 gallons. It was allowed to stand for two hours. It was then skimmed of the second cream, yielding a little over one-half ounce of pure rubber. These tappings were from the ground up to a height of about 4 feet.

Because of an accident, through which the tapper was severely injured, work was not resumed until February 4. Two of the same trees were tapped from 4 feet up to 8 feet, using water containing ammonia at the rate of one-half ounce per gallon. The latex continued to flow for thirty minutes. The latex was divided into two portions. Into one of these the filtrate from the previous tappings was poured while hot. There was no coagulation after standing for one hour. This portion was again divided. One-half was placed over the fire, the other allowed to stand, and both began to coagulate at once. The remaining half of the fresh latex was divided. One-half ounce of acetic acid mixed with one of these portions coagulated the rubber at once. The other portion was neutralized with formalin and allowed to stand one hour. A concentrated hot solution of ammonium sulphate was then added. In about thirty minutes there was a marked clearing of the mixture, the milky portion of the liquid settling to the bottom of the vessel, but there was no coagulation of rubber until a trace of acetic acid was added, when it coagulated at once.

The quality of the rubber secured by using acetic acid was at first very poor, having practically no tensile strength, but after thoroughly washing and rubbing it became as elastic as any other. Apparently if acetic acid is used thorough washing is necessary.

February 5 the same two trees were tapped as on the preceding day by freshening the old cuts. The latex flowed for only about fifteen minutes. It was then collected, strained, and divided into three equal parts. To the first portion acetic acid was added. There was a rapid separation of the milky part of the liquid, but no coagulation of the rubber. There was no coagulation when this acidified latex was heated, but when a small amount of ammonium sulphate was added it coagulated at once. The latex of the second portion was acidified with acetic acid and cold ammonium sulphate added. There was no coagulation until the latex had been made quite hot. The filtrate left from the preceding day was heated and poured into the third portion of fresh latex. There was no coagulation until the mixture was placed over the fire.

The next day the trees were tapped as on February 5, from 8 to 14 feet above the ground. The latex flowed only fifteen minutes. There was practically no flow from one of the trees except a very little in the uppermost cut. The bark was so thin at this height that it was difficult to make a suitable cut with a knife without injuring the tree. The latex, acidified with one-sixth ounce of acetic acid, and to this a hot solution of ammonium sulphate in 8 ounces of water added, yielded only a trace of rubber. There was no coagulation until the mixture had been boiled some time. Another portion of this day's latex, acidified with formalin, allowed to stand one hour, a hot solution of ammonium sulphate added, and the whole boiled, gave only a trace of rubber.

The remaining portion of the latex, acidified with acetic acid, allowed to stand one hour, and boiled, without the addition of ammonium sulphate, gave no better results.

The latex from the upper portion of the trees is very thin and watery and contains less rubber than that from the lower section of the trunk.

On February 7 these two trees were again tapped at the same height. The latex flowed fifteen minutes. One and one-half gallons of the mixture was acidified with 1½ ounces of acetic acid. It was left standing one hour without heating or adding ammonium sulphate. The rubber coagulated and creamed.

To another portion of this day's latex a portion of the acetic acid filtrate from the previous day was added without coagulation.

A third portion was left standing seven hours without being acidified; acetic acid then added, and allowed to stand overnight. Only a very small amount of rubber coagulated from this portion in twenty-four hours.

On February 8 the old cuts were freshened and the latex flowed for twenty-five minutes. It was collected and divided into three portions. The first portion, amounting to 1 gallon, was acidified with one-third ounce of acetic acid and allowed to stand. A second equal portion was acidified in like manner and violently stirred. The foamy scum which gathered on the surface of the liquid contained some rubber, and when the mixture was heated all of the rubber in the liquid coagulated at once. A third portion was acidified with acetic acid and at once heated. In five minutes the greater portion of the rubber had coagulated. It was left until it had boiled fifteen minutes, when the filtrate was perfectly clear. This rubber was very elastic, but lacked tensile strength. Continued boiling makes the rubber soft and sticky and robs it of both its elasticity and tensile strength. Upon cooling both of these qualities were restored to some extent.

The same two trees were tapped February 9 by freshening the old cuts and the latex flowed for twenty minutes. After straining it was divided into two portions. One of these was placed in a churn without acidifying and churned ten minutes without coagulation. It was then acidified with acetic acid and again churned seven minutes, when the filtrate was perfectly clear. The rubber was in very small particles, closely adhering to the wood of the churn.

The second portion was heated fifteen minutes without acidifying, when a part of the rubber coagulated. It was then acidified, but no additional rubber was obtained.

On February 11 the old incisions were freshened. The latex flowed slowly for fifteen minutes. A portion was boiled for three hours without acidifying, only a trace of rubber being secured, the liquid remaining milky.

Another portion was acidified and churned five minutes until all the rubber had coagulated in small pieces as before. A third portion was heated with sea water in proportion of 1 to 3. Very little rubber was obtained even when, after boiling, it was churned.

February 12, tapped the same two trees by freshening the old wounds. The latex flowed twenty-five minutes. It was divided into two equal portions. One lot was acidified and the other churned one hour without acidifying. No rubber was secured from either lot. This lot was left in the churn overnight. It had not coagulated in the morning. After acidifying, a part was again churned and a part was heated for one hour. The lot left in the churn did not coagulate, while that which was heated produced some rubber.

The trees were tapped by freshening the old wounds February 13. One tree flowed for twenty minutes, the other did not flow at all.

Part of the latex was acidified with acetic acid and heated to boiling for one hour. The rubber coagulated, but was all in small particles.

On February 14 the old incisions were freshened. One tree flowed twenty minutes, the other not at all. The methods of the preceding days were repeated, but there was only very slight coagulation of rubber.

On February 15 the trees were again tapped. One flowed fifteen minutes, the other almost not at all. To one portion of the latex dry sulphur was added. It was then brought to a boil and removed from the fire and acidified with acetic acid. A little rubber coagulated at once. There was complete separation of the milky liquid, but the rubber sank to the bottom. After cooling it was again boiled, when a part of the rubber again creamed. This rubber was very soft and not elastic. Another portion, acidified and churned one-half hour and then allowed to stand four hours, coagulated a small amount of rubber.

Again, on February 16, the old wounds were freshened. One tree flowed for fifteen minutes, the other not at all. Acetic acid was added to one portion and it was allowed to stand one hour, at which time there was no coagulation. Hot concentrated ammonium sulphate was then added and it was left standing thirty-six hours. While there was a clearing of the liquid, there was no coagulation until the mixture was heated. It coagulated, but did not agglutinate until it had been pressed together with the hands.

The last tapping experiment with these trees was made on February 18. One tree flowed twenty minutes, the other not at all. The latex was acidified with acetic acid and allowed to stand for one hour; ammonium sulphate added; allowed to stand for one-half hour without coagulation; after churning for ten minutes coagulation was rapid, and the rubber was very elastic.

TAPPING TO DETERMINE YIELDS.

After continuing these tapping operations for about a month to determine the best method of coagulation, it was decided that the most uniform coagulent was acetic acid. What may be called the acetic-acid method of coagulation is the addition of just enough of the acid to the ammoniated latex to slightly acidify it and allowing the mixture to stand. The greater the amount of acid added the more rapidly will the rubber coagulate. A modification of this method is to neutralize with acetic acid and add a boiling concentrated solution of ammonium sulphate. It is believed that the rubber produced in this manner is more pure than that coagulated with acetic acid alone, because of the greater precipitation of the proteids by the ammonium sulphate. However, when both acetic acid and ammonium sulphate are used the mass of rubber is very vesicular. The bubbles that are formed in the rubber mass are filled with the watery filtrate, which tends to render the drying of the rubber a slow and difficult process. Rubber coagulated by means of an excess of acetic acid is apparently fully as strong, although perhaps not quite so pure, and does not contain these vesicles.

During the period from April 5 to April 15, 8 ounces of dry rubber were obtained from two trees in nine tappings. The trees were tapped by the full-herringbone system from the ground to a height of 5 feet. The lateral cuts were 1 foot apart. The tapping was between 4 and 6 o'clock a. m. Ammonia was added to the water used in washing the latex from the wounds at the rate of one-half ounce per gallon. When the latex had stopped flowing, it was gathered, strained, acidified with acetic acid, and then a concentrated solution of ammonium sulphate was added. The mixture was then heated. As soon as the rubber had creamed it was skimmed and then washed and rubbed in an abundance of pure water. The rubber was not weighed until it had been thoroughly dried.

From April 17 to April 19 four trees were tapped, two each day on alternate days, to compare the results with every-day tapping. There was a slight increase in the yield in favor of the trees tapped every day. From July 15 to July 23 the two trees tapped between April 5 to 15 were again worked, using the same methods. The bottom and top laterals yielded as much latex as before, but the intermediate incisions yielded nothing. These two trees yielded $3\frac{1}{3}$ ounces of dry rubber as a result of nine tappings. At the same time one tree was tapped, using five vertical incisions from the ground to a height of 5 feet, with an oblique incision at the base, so as to bring all the latex to one container. This one tree yielded $3\frac{1}{6}$ ounces of dry rubber in nine days. This rubber was coagulated with sulphuric acid.

From July 26 to August 3 two trees were tapped daily from 5 feet up to 10 feet, using the half-herringbone system. These trees were 36 inches in circumference at 3 feet from the ground. They yielded $2\frac{3}{4}$ ounces of dry rubber in nine days. On July 27, a close, foggy morning, the latex only flowed in tears, which would have coagulated on the tree had not water been applied to wash it down.

On August 6 twenty-four trees were tapped, using the half-herringbone system, from the ground up to 4 feet, and $7\frac{1}{2}$ ounces of wet rubber were secured on this day. It was noted that there was wide variation in the amount of latex yielded by different trees, some yielding only a very little, others flowing freely. Acetic acid was used in coagulating this day's rubber.

On July 31 one tree that was very much branched was tapped, making half-herringbone incisions on each branch to a height of 5 feet from the ground. One-half ounce of rubber was secured. This concluded the work at Lihue from January to July, 1907.

TAPPING IN THE KOLOA GROVE.

During the period from May 21 to May 30 two of the oldest and largest trees in the Koloa grove were tapped, using the full-herringbone system from the ground up to 5 feet. These two trees averaged 44 inches in circumference at 3 feet from the ground, and both branched at about 6 feet. These had been much scarred and hacked by persons who had chopped or cut away the bark to see the latex run. There were a number of wounds that had not healed over, and the whole trunk of the tree was so rough that not all of the ammoniated water and latex could be collected at the foot of the tree. These two trees yielded 18 ounces of washed rubber in nine days' tapping. A good deal of the latex was wasted on account of inequalities in the bark. It is believed that had vertical incisions been used, instead of the herringbone, a very much larger yield of rubber would have been obtained.

From June 20 to June 28 two 4-year-old trees, 19 inches in circumference at 3 feet from the ground, were tapped by the herringbone system. These trees were bare of foliage, and yielded only three-fourths of an ounce of dry rubber in nine days.

From August 19 to August 28 the two trees tapped from May 21 to May 30 were again tapped by freshening the old incisions. The trees were in new leaf. The flow of latex was very slow at first, but increased each day until the end of the period. The largest yield of rubber was secured on the last day of the experiment. The two trees yielded 6 ounces of dry rubber in nine tappings.

On August 30 one tree was tapped, using the vertical method and coagulating with acetic acid and ammonium sulphate. The rubber from these tappings was lost on account of becoming moldy, so that no weights were taken. This tree yielded as much as any other two trees together. Between September 7 and September 20 the two 4-year-old trees tapped in June were again worked, this time yielding about one-eighth ounce of dry rubber at each tapping. During this period one large tree that had not been previously tapped was tapped from the ground to 7 feet with eight vertical incisions. It yielded only one-third ounce of washed rubber. The latex came out in small tears, and did not flow until ammoniated water was trickled over it. This tree was 40 inches in circumference. The latex was very yellowish, similar to one in the Lihue grove, which yielded practically no rubber.

No further tappings were made on the Kauai trees during 1907.

CONCLUSIONS.

The tapping experiments thus far undertaken, both on the Kauai trees and on various trees on Oahu and Hawaii, complete records of which have not been kept, indicate that there is very wide variation in the amount and quality of the latex yielded by individual specimens. It is therefore believed that every tree in every rubber plantation should be tested to determine the quality and quantity of latex before the tree is 2 years old. When individuals are discovered which yield an inferior quality of latex, or from which the latex does not freely flow, these trees should be rooted out and their places filled with cuttings from trees which appear to be of superior quality. In making these preliminary tests, it must be remembered that the flow from all rubber trees is poor on bright days, on the sunny side of the tree, and during the period of early leafage after the resting stage. The trees should be tested during the period of the day when the flow of the latex is highest—that is, between midnight and 8 o'clock in the morning. Wrong conclusions might be drawn from testing later in the day.

There seems to be some relation between atmospheric conditions and the flow of latex. Just what it is has not as yet been determined.

Double the amount of rubber can be procured from any Ceara tree by trickling water containing ammonia over the tapping area than by tapping without the use of water. The use of water will, it is believed, cheapen the cost of production rather than increase it. This method lends itself to rapidity of movement on the part of the tapping gangs and almost absolutely cuts out the production of scrap or waste rubber. The gathering of scrap rubber is more expensive than manipulating the water bag, and while one man working alone could not tap as many trees using water as not using it, by placing cloth water bags on each tree, so that they can be rapidly filled each morning before tapping, a very satisfactory system can be worked out.

It is believed that daily tappings for a period of two to four weeks or more will yield much better results than tapping on alternate days or at longer intervals over a period of several months. In our preliminary experiments, daily tappings for a period of nine days gave better results than tapping on alternate days for double the time, and the recovery of the tree was more rapid.

Trees which were tapped either just before the resting period or during the time when bare of leaves did not leaf out as quickly as neighboring trees which had not been tapped.

Young trees are not so readily injured by too deep cutting as old trees. The wounds in young trees heal very rapidly.

AMOUNT OF RUBBER PLANTED.

By January, 1908, 400,000 rubber trees had been planted in Hawaii, upwards of 90 per cent being *Manihot glaziovii*. The remainder are *Castilloa elastica* and *Hevea brasiliensis* in about equal proportions. There are now five large plantations in operation, and rubber trees are being planted by many independent farmers and planters. The oldest plantation is one of those at Nahiku. A first tapping will be made on some of the trees of this plantation during the summer of 1908, or as soon as they have reached a circumference of 20 inches, which is considered to be the smallest size at which it is safe or convenient to tap.

THE RUBBER OUTLOOK.

The whole tropical world is entering into the cultivation of rubber on a wholesale scale. Rubber is practically the only staple crop the supply of which has always come from what may be called natural sources. Even with the increase in the number of plantations during the last ten years 99 per cent of all of the rubber of commerce has been procured by the most wasteful and destructive methods from natural rubber forests. The rubber gatherer has preceded the tax collector in searching the unexplored and unknown forests in the interior of South America and all over the African Continent. He has destroyed forests and exterminated species in a relentless effort to secure enormous returns without the investment of proportionate capital. Wherever the rubber collector has gone no other need follow.

The cause of this frantic search for rubber-producing trees is to be found in the multitudinous uses to which this valuable material may be put. Because of its increasing scope of usefulness the rubber consumers have never been able to procure enough of the raw material to satisfy the yearly demands, so that the end of every decade has witnessed a marked increase in its value.

While it has been long recognized that certain species of rubber-producing trees, notably the Para and Assam rubbers (*Hevea brasiliensis* and *Ficus elastica*), were amenable to cultivation, tropical planters have only recently awakened to the enormous possibilities of a cultivated product which in its raw condition commands a price of $3,000 a ton or more. There is now apparently a race among countries having lands available for rubber production to see which can get the largest acreage of rubber trees into bearing in the shortest time, in order to harvest the marvelous profits which seem almost absolutely certain.

The present acreage of cultivated rubber probably exceeds half a million acres, and every year sees additional tens of thousands of acres planted. One of the uncertain factors has been the time which must elapse between the first investment in land, seed, and plants and the realization of the planters' golden dreams. Hundreds of rubber-plantation companies have been formed and floated in Europe, the United States, Mexico, and the East Indies, some to operate concessions containing areas of wild trees, others seeking in all haste to plant as large an acreage as possible of one or the other species of rubber-producing plants.

While the uses of rubber are capable of almost indefinite extension, and while new purposes to which this material may be put are discovered every day, the very large areas which have been and will be planted will undoubtedly seriously affect present prices as soon as large areas have commenced to bear. At the present cost of production and at the present market returns the profits are enormous. If prices fall to a third of those of the present day, plantations already in operation will be able to continue to produce rubber at a profit of at least 100 per cent. It will doubtless be with rubber as it has been with all other raw products—that the cheapening of price will increase the consumption. The profits already obtained from the cultivation of rubber have been responsible for much extravagance in management and operation. No one can predict at what period the fall in prices will begin, but it will probably not be for another ten years at least and may not be in twice that time.

The best way to keep up the price is to produce only rubber of the best quality or of as good quality as is compatible with normal rather than extravagant management. When prices begin to go down, the plantations which will first feel it will be those in locations least suitable to the growth of rubber trees, or those which are overcapitalized or mismanaged.

The Ceara variety of rubber tree grows in Hawaii better than in its native habitat. The rapidity and vigor of growth on our plantations is remarkable. Many trees show a growth of from 10 to 15 feet or more during a single season, with girth measurements in proportion. While the trees on the Hawaiian plantations are more or less subject to fungus diseases and insect attacks, no specially destructive disease and no insect pest peculiar to this plant alone has as yet gained entrance to this Territory. The diseases and pests are those affecting forest trees in general.

The methods of tapping which this station has developed and the preliminary experiments already made indicate that healthy average trees of the Ceara variety, which have attained a trunk diameter of 6 to 8 inches at 3 feet from the ground, will yield from 5 to 10 or more pounds of crude rubber each per annum. As most of the Hawaiian plantations have made their beginnings on the prospect of securing 1 pound of rubber per tree per annum at the end of five years, it is our sanguine belief that the cultivation of rubber trees of this variety is on as sure and firm a foundation in Hawaii as in any other part of the world. Furthermore, the Ceara variety seems better adapted to Hawaiian climate, soils, and conditions than any other rubber-producing tree which has as yet been introduced. Its extreme rapidity of growth and its adaptability to widely varying conditions of soil and climate, its large yields, and its early maturity indicate that its cultivation will be the most advantageous.

INSECT ENEMIES OF THE CEARA RUBBER.[a]

The following information occurs in the entomological records of this station regarding the insects injurious to the Ceara rubber tree in Hawaii:

SEED BEDS.

A wireworm (*Elateridæ*, species undetermined) destroyed many seeds in the seed beds at Nahiku the first season. The source of the pests was traced to the horse manure used in the seed beds, the manure heap offering a breeding place to the larvæ of this beetle. The wireworms entered the seeds through the openings made in filing, feeding on the interior. Seeds that were not filed through escaped injury from wireworms. Sterilization of soil and manure used in seed beds as described above for nematodes will check the development of this pest.

THE TREE.

The following scale insects (Coccidæ) have been taken from Ceara rubber trees in Hawaii: *Saissetia nigra*, *Saissetia oleæ*, *Aspidiotus cyanophylli*, and *Pseudococcus* sp. (mealy bug).

In no instance had serious results attended the presence of these insects. Lack of injury is due largely to the young and vigorous growth of the trees. The vigor and health of the trees must be maintained.

A bark beetle, *Xyleborus affinis*, followed injury to the tree from tapping on Kauai. The snout beetle, *Pseudolus longulus*, likewise found entrance in the unhealed scars from tapping. The former species was rather abundant in the single case observed and gave evidence that under favorable conditions for development it might work serious injury. The latter species is not considered important. Both species are borers. Care must be exercised in keeping all dead and partly dead limbs and trees cleared away, and all wounds from tapping that do not heal over should be painted as soon as the tapping is discontinued to prevent these borers from gaining entrance.

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[a] By D. L. Van Dine, Entomologist.

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