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HAWAII AGRICULTURAL EXPERIMENT STATION

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EUPHORBIA LORIFOLIA,
A Possible Source of Rubber and Chicle.

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PHYSICAL AND CHEMICAL PROPERTIES OF LATEX OF EUPHORBIA.

BY

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Developments brought forward, during the last ten years, in the commercial aspect of the rubber industry, due to the wide range of uses to which this product may be applied, have caused a wide spread investigation upon the physical properties and chemical composition of the latices from practically all the common latex-bearing trees and shrubs. These researches have been partly stimulated by the apparent failure, heretofore, of placing the manufacture of synthetic rubber upon a commercial basis of sufficient remuneration to compete with the natural product. On the other hand additional stimulation has been derived, for both the manufacture of the synthetic product and the investigation of latices, by the high price which rubber has been able to maintain. While there is room for doubt as to whether scientists will ever be able to duplicate the natural rubber with a synthetic product, it is almost an absolute certainty that a synthetic substitute will, in the near future, be made an article of commerce.

While these investigations upon latices have been primarily stimulated by a search for a new source of rubber, nevertheless they have brought out developments of some value concerning the resin content. Since this substance is known to be a constituent in widely varying quantities of all latex-bearing as well as some non-latex-bearing trees.

At present the only latex-bearing trees of known commercial value in Hawaii, are those which are used as a source of rubber and are largely Ceara, Para and Castilloa. Limited numbers also exist of Manihot dichotoma, M. piauhiensis, Ficus elastica, F. religiosa, and species of Cryptostegia, Sapium, Kickxia, Calotropis and other genera.[1]. The attention of this station was called to a species of Euphorbia (Euphorbia lorifolia, native name Koko or Akoko, meaning blood) which contains an unusually large quantity of easily obtained latex and occurs in large numbers in these islands. The first sample was sent into this laboratory by Mr. J. F. Rock and was taken by him from trees on the island of Hawaii, covering several thousand acres on that island alone. The area is at present under lease for pasturage, however, large areas of this same tree are said to exist upon the other islands of the group. In view of the ease of obtaining the latex, in other words, the ease of tapping and the large quantities of latex which can be obtained from one tree, coupled with the large areas which exist in the islands, it was considered to be of sufficient importance to warrant some investigation as to the composition and properties of this latex.

Commercial importance attaches to any rubber yielding latex which may be obtained in reasonably large quantities. Euphorbia lorifolia, the tree reported upon in this bulletin, occurs in a continuous area of 6000 acres in one section of Kona. The yield of latex shown by the experiments reported herein is remarkable, indicating as it does the possible collection daily per laborer of 34 pounds dry substance or 20 pounds pure resin, without considering the rubber content of the latex. The comparison of the whole latex of Euphorbia and Ceara rubber is of interest in showing a very high proteid content in Ceara latex. The fact that the proteid material is so largely removed by washing and pressure indicates how easily this material is removed from the rubber.—E. V. WILCOX.

1. See Hawaii Experiment Station Bul. No. 19.

Accordingly a large quantity was obtained and considerable work and time spent upon obtaining information regarding its physical and chemical properties.

PREVIOUS WORK ON EUPHORBIA.

So far as is known this particular species of Euphorbia is found in no other part of the world, being a native of Hawaii. However, this tree is of a widely distributed genus and some previous work has been done upon this genus of trees and plants to escertain the nature of the latex and its caoutchouc-content. H Journelle[1] reports on E. elastica, a native tree of Madagascar which yields a good quality of caoutchouc and is easily coagulated by boiling. The yield of caoutchouc he stated to be at least 320 grams per litre of latex (about 11.3 oz. per quart). He also merely mentions another species of rubber-bearing Euphorbia; namely, E. intisy, a native shrub of Madagascar. J. McC. Sanders[2] reports a species (E. elastica, Palo amarillo) growing in Mexico the latex of which contains about ten per cent of rubber and the coagulated product contains about 50 per cent resins. P. Olsson-Seffer[3] reports concerning E. fulva (Palo amarillo) a tree occuring in Mexico the latex of which contains 7.3 — 15.7 per cent rubber and 19 per cent upwards of resins. Commenting upon this latex he says it might possibly be commercially exploited as a source of rubber. O. Rebuffat[4] analysed the latex of E. candelabra, which grows abundantly in Eritrea, Africa, and claims to have found 40 — 50 per cent of good quality rubber in it. An analysis of the latex of E. lactiflua[5] shows it to have a resin content of about 28 per cent and about 4.1 per cent caoutchouc. N. H. Cohen[6] worked on the latex of a South African Euphorbia, the coagulated form of which contained 70 per cent of resins. In addition a great deal of work has been done upon the medicinal value of Euphorbia shrubs, many of which are known to contain alkaloids.

Some of the results above referred to are open to serious questions as to the caoutchouc content. Especially the E. elastica

1. Comptes Rend. 1905, 140, 1047-1049.
2. An. Inst. Med. Nac. (Mex.) 10 (1908) pp. 67-74.
3. Daily Cons. & Trade Rep. (U. S.) 1909, No. 3516.
4. Atti. R. Inst. Incoragg. Napoli 6, Ser., 59 (1907) p. 89.
5. An. Agron. (Santiago de Chile) 4 (1909) No. 3-4 pp. 189-237.
6. Arch. Pharm. 1908, 246, 515-520.

the analysis of which shows 30 per cent of caoutchouc, and more especially E. candelabra the analysis of which shows a rubber content of from 40 — 50 per cent. However, these high results may be explained by the probability of the analyst reporting resin with the caoutchouc. The latex of Para rubber contains only about 40 per cent caoutchouc.

PROPERTIES OF LATEX FROM EUPHORBIA LORIFOLIA.

The latex is white, viscous, has milky appearance, strongly acid reaction, and a rather pleasant aroma peculiar to itself. It is of a rather highly combustible nature when the moisture is evaporated off and burns with a strong flame and dense smoke fumes. The latex has a special gravity of about 1.045 at 20°C. and quickly darkens on contact with the atmosphere, which is probably due to an addition product formed between the oxygen of the air and the unsaturated hydrocarbons of latex. However, there is also a strong possibility of this darkening being due to the proteids. This same property of darkening is noticeable upon the tree. In this form the latex is capable of being re-emulsified on mixing with water. The latex does not ferment readily and can be preserved indefinitely without even a coagulation or separation, by the addition of a small quantity of formalin. Under the high power microscope glubules are only faintly discernable.

COAGULATION.

At the outset it was found that most of the ordinary methods of coagulation were without apparent effect upon this latex. Accordingly a series of methods of coagulation were planned and the following results obtained:

1. Acetic acid when added in small quantities produces no coagulation even on long standing, but upon the surface of the latex where the drops of acid strike, the particles are set into a rather violent action and appear to be temporarily coagulated about the drop of acid, but upon strirring this disappears. This suggested the possibility of producing a coagulation with larger quantities of acetic acid with the result that it was found that by addition of extremely large quantities (about 1 part strong acid to 1 part latex) the latex thickens upon stirring and the whole coalesces into a mass, the physical condition of which is

similar to the white of an egg. Other acids were without effect.

2. A small quantity was treated with ammonium oxalate diluted and a small amount of calcium chloride added. There was a precipitation of calcium oxalate but no coagulation of latex.

3. Dilution with water was without effect even upon long standing.

4. Neutralization with alkali produced no coagulation.

5. On addition of enough alkali to produce a 6 per cent solution, no coagulation resulted.

6. Acid juice of the sisal plant was tried to see the effect of plant juices, and it appeared to act similarly to the acetic acid, with no coagulation.

7. Salt solution (sodium chloride) was without effect.

8. Formalin produced no coagulation, alum and soap solution likewise.

9. Lead acetate acts as a precipitant and carries down the whole mass, leaving a clear supernatant liquid, while alumina cream, another clarifying agent was without effect.

10. Ammonium sulphate, generally recommended as a precipitant for proteids and albuminoids was without effect except when added in the form of the dry salt in large quantities. The action of the salt was to remove the water from the latex to form a solution, which removal left the latex in a coagulated condition from which re-emulsification was incomplete.

11. Addition of alcohol to the latex acted similarly to acetic acid, namely, small quantities were very ineffective. On gradually increasing the proportion of alcohol and stirring the whole up to a certain stage it gradually coalesces into a strongly viscous mass. Addition of alcohol beyond this stage causes a reversion of the mass to its original liquid state. On the other hand pouring or better spraying the latex into alcohol produced immediate coagulation into a "cheesy" mass which will not re-emulsify by subsequent prolonged boiling with either alcohol or water.

12. Action of heat. This proved to be the most promising method of coagulation. Up to a temperature of 75° C. the latex maintains its original form but between 80° — 90° C. the latex thickens and at about 90° C. assumes a "cheesy" form. This mass will partially re-emulsify upon boiling with water immediately but if maintained at 90° C. for several hours to

become thoroughly coagulated and the whole allowed to remain until the following day to cool, it then will remain in its coagulated state even on prolonged boiling with water. This mass is cohesive and can easily be rolled into balls which on standing in the air turn brown and lose moisture quite rapidly.

Of the above methods Nos. 11 and 12 are the only ones which were effective and No. 12 is the one most recommended for a coagulant. The coagulation obtained is not one in the sense generally spoken of in reference to rubber latices, that is, there is absolutely no separation of clear liquor, upper layer of caoutchouc, etc. But the whole action may be better described as a coalescing of the entire latex into one mass, moisture included. This mass is extremely adhesive but does not possess the strong cohesive properties of a coagulated latex from Para or Ceara trees and does not appear to contain a very large per cent of caoutchouc, but to be composed in greater part of resins.

ANALYTICAL RESULTS.

In order to make an analytical examination upon the latex it was necessary to work upon the "cheese." The action of solvents such as chloroform, benzol, carbon bisulphide, etc., when shaken with the milky latex only increased the volume of the emulsion. Accordingly analyses were made upon the "cheese" by using a series of extractions using alcohol first, then acetone followed by chloroform. The following results were obtained.

COMPOSITION FO LATEX IN PER CENT.

	1	II	III	IV
Alcohol extract	50.66	35.17	37.24	37.10
Acetone extract	10.46	19.90	22.60	17.45
Chloroform extract	14.79	14.24	17.34	14.72
Insoluble residue	24.09	30.69	22.79	30.73

These results are given on the basis of a moisture free latex. The alcohol extract represents gums, carbohydrates and resins, the acetone extract the resin insoluble in alcohol and the chloroform extract was a caoutchouc-like substance, and will hereafter be referred to as caoutchouc. The insoluble residue was obtained by difference and will be described later. The four samples represent three different tappings: No. 1 was obtained by extraction in the cold; that is, by allowing it to stand in contact with solvents at room temperature, No. 2 is the same sample extracted with boiling solvents, while Nos. 3 and 4 are separate tappings extracted with boiling solvents. A more complete analysis of the latex is as follows:

MOISTURE AND SOLID MATTER.

	per cent I	per cent II	per cent III
Solid matter	41.59	40.92	49.15
Moisture	58.41	59.08	50.85

ANALYSIS OF SOLID MATTER.

Gum	1.50
Resins	55.95
Caoutchouc	15.80
Protein	12.66
Reducing sugars	trace
Nonreducing sugars	.68
Pentosans	.84
Ash	3.44
Undetermined	9.11
	100.00 per cent.

The above analysis represents the average results of the analyses made upon two tappings. For clearness it may be necessary to state that the gum (1.5 per cent) was obtained by treating the alcoholic residue with water and determining the per cent of this water soluble constituent. Of course this will also contain part of the sugars referred to in this same table but by no means all of them, as the carbohydrates are not all completely soluble in alcohol. The remainder of the alcoholic residue was added to the acetone soluble resin and the whole classified as resins, even though there is considerable difference in the color and other properties of the two resins. The latex contains no starch at least not in sufficient quantities to be detected with iodine.

COMPOSITION OF THE ASH.

Silica ($Si\ O_2$)	.89
Iron and ($Fe_2\ O_3$) Aluminum oxides ($Al_2\ O_3$).	1.64
Manganese)$Mn_3\ O_4$)	.00
Lime (Ca O)	6.07
Magnesia (Mg O)	14.76
Potash ($K_2\ O$)	12.94
Soda ($Na_2\ O$)	21.72
Sulphur trioxide ($S\ O_3$)	3.90
Phosphoric acid ($P_2\ O_5$)	1.66
Carbon dioxide ($C\ O_2$)	36.42

This table indicates that the mineral portion of the latex is made up of the more soluble constituents of the soil.

ALCOHOL-SOLUBLE MATTER.

On extracting the coagulated latex with alcohol a yellow solution is obtained which on cooling deposits a flocculent residue. On evaporation of the whole to dryness a dark brown resin is obtained which is more or less brittle at room temperature and softens at 50° C. and as stated above contains a small per cent of water soluble gums. A short study was made upon the nature of this resin and an attempt made at a classification. The following values were obtained: Acid value 9.46, Saponification value 38.10, iodine number 152.30.

Resins are classified by Allen[1] according to their content of resin acids, resin esters and resenes, the latter being apparently inert bodies of unknown composition. The acid value was obtained by titrating an alcoholic solution of the resin, while the saponification value was obtained by saponifying the resin with alcoholic potash and determining the amount of potash used up in the reaction. Figures represent milligrams of potassium hydrate per gram of resin. These figures are comparatively lower than a great many resins and indicate that the content of resin acids and esters is rather low and that the substance is in large part either an anhydride of a resin acid or to be classified as an indifferent resene compound. The iodine value is fairly high and indicates the unsaturated condition of this organic substance as shown by the readiness with which it combines with iodine chloride (I Cl). The iodine absorption was carried out according to the Hübl method and absorption allowed to proceed only three hours, as the iodine value was found to vary greatly with the time.

ACETONE EXTRACT.

This extract was also a yellow solution, but lighter than the alcohol extract. On evaporating this to obtain the resin, a vitreous, almost transparent resin, of a reddish yellow color was obtained. This resin is apparently a very good product, brittle at room temperature and softening at about 65° C. A short study of the nature of this substance revealed the following

1. Allen, Com. Organic Chem. Vol. II, pt. III p. 141.

data: Acid value 0.0, Saponification vàlue 0.0, iodine number 163.0.

This product undoubtedly is to be classed as a resene compound. It is not acted upon by boiling with alkali, in other words is unsaponifiable. Allen says of these compounds that "they possess no characteristic chemical properties and do not appear to be alcohols, esters, acids, ketones or aldehydes." This class of resins is used in the manufacture of varnish, their value being due to their chemical inactivity. Tschirch[1] presents the theory that this class of compounds belongs to the oxyterpenes or oxypolyterpenes.

CAOUTCHOUC.

The portion of the latex soluble in chloroform is radically different in its physical properties from the two previous extracts. Upon evaporation a caoutchouc-like substance is obtained which remains soft and sticky at ordinary temperatures. The extraction with chloroform is complete, and easily filtered from the insoluble residue, which indicates the absence of the insoluble residue characteristic of Para and Ceara latex which swells upon treatment with chloroform and renders the extraction with this solvent incomplete. While there is no question of the solubility of caoutchouc in chloroform, its action is greatly retarded in the Para and Ceara rubber by the presence of this insoluble constituent the composition of which Weber[2] found to be expressed by the formula $C_{30}H_{68}O_{10}$. The action of chloroform on Euphorbia rubber as noted above indicates the absence of such an oxygenated compound in the rubber from this tree.

No tests were made to prove absolutely that this chloroform soluble matter is pure caoutchouc chemically, beyond its solubility in various solvents. A solution of it in chloroform or carbon bisulphide is precipitated out as a white precipitate on pouring into alcohol or acetone. While this is one property of rubber it is not proof of its presence as other hydrocarbons insoluble in alcohol and soluble in chloroform may have the same properties. It hence only indicates the possibility of its being caoutchouc. J. Torrey[1] has proposed a colorimetric method for the determination of rubber based on the deep red color pro-

1. Tschirch "Die Harze und die Harzbehaeter" 2nd ed. p. 1079.
2. Jour. Soc. Chem. Ind. 1900, p. 215.

duced when rubber is heated in nitric acid (sp. g. 1.42) and then the whole dissolved in alkali. The product from Euphorbia responds to this reaction beautifully, but the two resins obtained also react with equal intensity. While it was not considered of sufficient importance to make an elaborate study of this substance to prove absolutely its composition, from the data obtained I am of the opinion that it would be identified as a caoutchouc body. However, it appears to be an inferior grade of rubber and lacks the strong cohesive properties.

INSOLUBLE RESIDUE.

The residue left from extractions with the above solvents is a white flaky substance which can be ground to a rather fine powder. While it appears to contain a small per cent of gum or resin it is apparently insoluble in all the common solvents. The most striking thing noticeable is the high nitrogen content, which amounted to 6.88 per cent and is equivalent to nearly 50 per cent protein. Subsequent tests to prove the presence of proteids gave positive results. Millon's reagent (a solution of mercurous nitrate, holding nitrous acid in solution) gave a reaction for proteids both in this insoluble residue and in the original latex. Other minor tests were obtained which added to the proof of the presence of this class of compounds in appreciable quantities. This residue is not acted upon by any of the strong acids at ordinary temperatures but when boiled with strong alkali forms a colloidal solution which on standing precipitates as a flocculent precipitate.

In view of the fact that the presence of alkaloids has been claimed in Euphorbia, several of the more important methods of detecting this class of compounds were applied to the latex and also to the insoluble residue, none of which indicated their presence.

DRY DISTILLATION.

On subjecting this latex to destructive distillation some interesting results were obtained, thus opening up a line of work which would require a thorough study to reach any conclusion as to the nature of the distillation products. I will only briefly state that the main product is a resin oil with a green fluorescence similar to crude petroleum, which amounts to about

1. India Rubber Jour. 1905, 30, p. 417-18.

25-30 per cent of the original latex and passes over at about 250° C.

DISCUSSION.

The physical constitution of the caoutchouc bearing latices is generally considered to be an emulsion, the stability of which depends upon the maintenance of a state of equilibrium within this emulsion. The coagulation of the latices consists essentially in disturbing this equilibrium with the aid of chemical or physical means. Thus bringing about a segregation and subsequently an aggregation of the particles making up the emulsion, those of specific gravity lighter than water (which would include caoutchouc and many resins) would rise to the surface, and since these constituents are the dominating ones, they would carry the major part of the remaining constituents such as mineral matter, carbohydrates, proteids, etc., with them. These latter substances, howover, are removed in large part by subsequent washing.

Since the Euphorbia latex refused to respond to most of the latex coagulants commonly used and since it is readily coagulated by means of alcohol and heat, (both of which are coagulants for albuminoids and proteids), it would seem that the coagulation of Euphorbia latex is primarily due to the coagulation of these bodies. A thorough explanation of the phenomeon of coagulation which is acceptable to all interested, is yet forthcoming. However, I am of the opinion that the proteids are a big factor in the above method of coagulation. Different forms of proteids being affected or unaffected by physical or chemical agents according to the properties of the proteids present, offers a theory as to the action of various coagulants, and why the different coagulants act so differently on latices of various sources and properties. Furthermore the action is apparently a physical one.

The resolution or re-emulsification which the Euphorbia latex undergoes on adding an excess of alcohol as previously referred to is probably due to a resolution of the proteid in this solvent. Heat and alcohol both being dehydrating agents, offers an explanation of the coagulation as being a result of dehydration but at all events, even though this be partially true, the effect upon the proteid appears to be the dominant factor.

The function of latices is also a matter yet open to wide discussion. For this reason, primarily, the mineral constitutents of the ash were determined and have been tabulated, as well as the carbohydrate and nitrogen content. Some investigators have advanced the theory that the latex is an excretory product of the plant, others that it acts as a source of stored up energy, and D. Spence[1] likens its function in rubber trees to that of glycogen in the liver. The theory of its acting as a source of plant food appears the more acceptable from data at hand, namely, high nitrogen content and the composition of the mineral constituents. Coupled with this is the fact that the green fruit of the Sapotaceae (source of Balata rubber) contains a latex which is lacking in the ripe fruit. There is also a strong possibility of the latex acting as a moisture conserving agent for the plant and, through the moisture content of the latex, as a conveyor of plant food.

COMPARISON OF EUPHORBIA WITH CEARA AND BALATA.

In order to compare the properties of the Euphorbia latex with some of the other latices obtainable at the Experiment Station, samples were collected from Ceara and Balata and the resin and caoutchouc content examined. Balata being identical with the so-called chicle, the main constituent of chewing gum, it was considered to be of sufficient importance to compare these resins, since the Euphorbia resin serves as an excellent substitute for this purpose. And while the physical properties of the two latices appear to differ as well as the physical form of the caoutchouc the resins soluble in alcohol and acetone are similar. On the other hand the resins from the Ceara were soft and entirely different from the other two. The following table gives a comparison of analyses made upon the three varieties of latex.

LATEX ANALYSES.

	Balata per cent	Ceara per cent	Euphorbia per cent
Resins alcohol soluble	42.80	7.28	34.70
Resins acetone soluble	4.91	1.30	21.25
Protein	4.35	13.16	12.66
Ash	not det.	2.54	3.44
Caoutchouc	13.95	75.72	15.80

The caoutchouc was determined in the Ceara by difference for reasons already referred to while that in the other latices was determined by extraction with chloroform. It is impossible

1. Biochem. J. 3, 165.

to make an extraction of Ceara by chloroform in a reasonable length of time. The insoluble residue left from the balata amounted to 38.4 per cent and was unlike that of the Euphorbia in that if contained a higher per cent of an insoluble gum or resin. A sample large enough to make a further study of this product was not obtainable, this sample being taken from a number of green fruits. The Ceara latex was obtained from trees on Tantalus which had not been tapped for about two years.

Weber[1] comments upon the protein content of latices and considers the presence of as much as 5.6 per cent in a dry latex of unknown origin and also another of Para containing 4.3 per cent, highly questionable. All the figures obtained in my analyses were duplicated and several different tappings analysed from which there is no possibility of the high percentages of protein being abnormal.

SUMMARY.

The best means of coagulating the latex from Euphorbia lorifolia is with heat or by spraying the latex into alcohol. The former method appears to be the preferable.

The constituents which appear to be of most commercial value are the resins, the acetone soluble resin being a product of very fine texture and physical appearance.

The chaouchouc like substance appears to be of an inferior quality in comparison to the better grade, however, it might find use as a low grade product.

Distructive distillation of this product or possibly of the wood from this tree presents an unexplored field which may possibly offer a theme for future work. By distilling wood and all a more complete recovery would be possible.

In event of a commercial working of this latex by means of volatile solvents, the insoluble residue with its 40-50 per cent protein would have as a means of its disposal a possibility of its sale as a fertilizer on account of its high nitrogen content.

Acknowledgements are due Dr. E. V. Wilcox and Dr. W. P. Kelley for interest taken in this work as well as valuable suggestions offered from time to time, also to Hind, Rolph & Co. for their co-operation in securing the samples of latex and to Mr. Valentine Holt for obtaining the sapota fruit.

The Chemistry of India Rubber, C. O. Weber, p. 5.

OCCURRENCE OF EUPHORBIA LORIFOLIA AND TAPPING EXPERIMENTS.

BY

W. A. ANDERSON.

In February, 1912, announcement was made of the discovery on Hawaii, by Mr. J. F. Rock, of a forest of native trees belonging to the Euphorbiaceae. The yield of latex from these trees, as reported by Mr. Rock, was so large as to invite further investigation with a view to determining their commercial possibilities as rubber producers. The writer visited the forest in May for the purpose of securing latex samples, and of observing the adaptability of the trees for tapping, and the possibility of adding them to the varieties now being cultivated in the Territory for rubber.

The trees are growing among other forest growth on several thousand acres of Government land under lease to the Puuwaawaa Ranch, in the Kona District, Island of Hawaii. They are said to occur elsewhere, notably at Kukaiau where they are known by the Hawaiian name of "Koko" (bloody or juicy tree.) They were found at an elevation of about 3,000 feet, in very thin a-a soil with frequent out-croppings of pahoehoe The trees large enough for tapping are distributed at irregular intervals among other trees. The ground is covered with seedlings one to six or eight feet high, mostly of the Euphorbia trees, forming an immense nursery. There is very little undergrowth beside these seedlings. Many of these have been eaten off at the top by cattle, and have started growing again from eyes along the stems. The region is very dry, with a precipitation of not over twenty inches per year. At the time of the visit, at the end of what is usually the rainy season, only one inch of rain had fallen in five months. At this time the trees were putting forth new leaves, and appeared to be just entering on the summer's growth. This was taken to indicate ability to survive severe drouths.

The normal size of mature trees cannot be judged from the present forest. No large trees were seen, the largest being not over ten inches in diameter. A number of dead and dying trees no larger than this were noticed. But no conclusion can be drawn from this as to the size they might attain under favorable conditions. The thin soil, frequent severe drouths, and the cattle, combined, may have prevented the trees reaching full maturity.

To get further information on this subject, as well as to determine their adaptability to different conditions, a number of the seedlings were taken to Nahiku, and planted at the substation in deep, cultivated soil, at an elevation of about 700 feet, with a rainfall of over 100 inches per year. These started growing immediately and at the end of one month some had grown three inches. They will furnish material for observing the rate of growth under cultivation, and their suitability as a plantation tree.

TAPPING.

The tapping of the forest presents no serious obstacles. While the a-a is somewhat difficult to walk rapidly on, the absence of undergrowth, aside from the seedlings above mentioned, makes access to the trees easy. In the portions visited, there are about 50 to 75 mature trees per acre, at distances which, while naturally irregular, are not too great for successful tapping. By judicious thinning of the other forest trees and allowing the seedlings to grow at proper intervals this irregularity could be gradually overcome, and a forest developed with trees regularly spaced and at any desired distance apart.

Some of the trees had been tapped in February. Those which had been tapped by a series of diagonal incisions, a foot or so apart, had apparently suffered little injury. Some of these were tapped again May 28th and the flow was about the same as in February. This would indicate that they can be tapped as often as once in three months. They cannot be tapped every day. Each incision draws the latex for several inches from the cut, and tapping on the following day gives little flow.

The latex flows very freely and in large quantities. It spurts out apparently under considerable pressure, and flows rapidly for a few seconds, after which it flows more slowly for about a half hour. From the first six trees, tapped in the forenoon, about two and one-half pounds of latex was obtained. Other trees, tapped in the afternoon, gave a much smaller yield. The latex is very sticky and resinous. Where it had dried on the tree since the February tapping, it resembled spruce gum in appearance, feel and taste. It has an acid reaction as it comes from the tree, but shows no tendency to coagulate in bulk. Considering the fact that the trees were tapped when the foliage was very light, during a drouth which had lasted for five months, and near the middle of a bright, sunny day, the yield of latex was very large.

The conclusions drawn from the observation of this forest are: That the trees will grow on very thin soil, at high elevations, with small rainfall, and will live and yield large quantities of latex through long and severe drouths; that they reproduce freely, and the seedlings are very hardy; that they can be tapped much like the Castilloa tree, and about as often; and that this particular forest furnishes an excellent opportunity for proving the value of the tree as a rubber producer, providing, as it does, trees large enough for tapping, and near enough together, and in large enough numbers to tap economically.

Tapped by the full herring bone system, with U shaped excisions supplemented by incisions in the bottom of these cuts, as is done on some Mexican Castilloa plantations, one experienced man, on reasonably even ground, can tap about 200 trees per day. With an average yield of, say, one half that reported for the six trees mentioned above, one man could thus collect 41 2-3 pounds of latex in one day's work. The profitableness of the operation then depends on the amount of commercial material in the latex, the cost of getting it out, and its market value. The latex obtained was forwarded to the Station at Honolulu for coagulation and analysis.