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Canadian Section.

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DR. R. F. RUTTAN IN THE CHAIR.

THE RUBBER AND RESIN CONTENT OF THE DESERT RUBBER-PLANT "GUAYULE," IN RELATION TO RAINFALL.

BY FRANCIS E. LLOYD, M.A.

In an earlier paper* the view has been advanced that the amount of rubber secreted by the guayule, *Parthenium argentatum* Gray, varies within wide limits, inversely with the amount of soil water available. It was shown, however, that the amount of rubber which may ultimately occur within the secreting cells (which are chiefly those of the parenchyma) may be quite as great in those cultivated plants which receive a maximum water supply, as in feral plants, while the amount calculated to the total dry weight of the plant remains small. This is explained by the great changes in the character and especially in the volume relations undergone by the various tissues when the plant accommodates itself to the change from xerophytic to mesophytic conditions. The most obvious of these changes is seen in the thickness of the cortex ("bark"), which is relatively much less in well-watered plants, this constituting an important factor in determining the amount of rubber relative to total dry weight.

Correlated with the soil water supply is also the rate of secretion within the cell, which is much slower in well-watered plants. Thus a feral plant will show a much larger amount of rubber within the cells at the close of the normal wet season, say three months after the earliest effective rainfall of summer (in Chihuahua), than will an irrigated plant after six months of rapid growth, while the latter, during a subsequent period of enforced drought, will make marked advance toward attaining a full complement of rubber.

From the study of plants grown under such extreme conditions as regards water supply, it was to be inferred that variations in rainfall, either from season to season in the same locality, or as correlated with geographical conditions, would be accompanied by variations in structure and rate of rubber secretion in the same directions in plants in their normal habitats. Indeed, one striking example was afforded and has been described elsewhere† as well as in the publications above cited, but, at the time, no analyses were available, so that the divergencies of structure and rubber content had to be described in histological terms only.

Since then, the writer has received samples of plants in three lots from as many separate localities which bear out in a striking way the inference made, both in regard to the general habit of the plant and as to the rubber content in terms of total dry weight. These were very kindly furnished me by Sr. Ramon Muñoz, accompanied by the following data. The material was collected in December, 1912. During that year and during the latter half of 1911 the rainfall had been "very abundant," and in consequence an "abundant and rapid reproduction and growth" in all the guayule fields was reported. It is not possible to say in exact terms what "abundant" means, but we may suppose that, in a country where 12 to 15 inches is not considered meagre, 20 inches would fall somewhere near the mark. However this may be, it is more to the present

purpose to point out that the region where the plants of Lot 3 grew is recognised as having a distinctly more abundant rainfall than those lands lying farther to the west. It lies on the eastern border of the guayule area, partly in the states of Nuevo Leon and partly in San Luis Potosi. These plants have a very different appearance from those of the other lots, namely, Lot 1 and Lot 2, both from guayule fields situated well within the area of distribution, and, indeed, markedly different from that of any guayule which I have seen growing in the field. Rather do they resemble irrigated plants in their slender twigs, yellowish bark, and greater shrinkage upon drying, the last-named character becoming evident in deep longitudinal folds. The plants of Lot 1 were four small seedlings, of which one was three years old and the remainder two, and except for a growth rate (viz., about 6 cm. yearly) somewhat greater than usual (about 3.5 cm. yearly) presented nothing unusual. The plants of Lot 2, also four in number, were of a type of guayule generally recognised as the "best." They were stocky plants, with fewer and thicker branches and twigs, grey in colour and generally conforming to the popular conception of "macho" (male) guayule, while the plants of Lot 3 are regarded as "hembra" (female). This distinction I have discussed elsewhere (i.e.), but briefly the alternative views are that we are dealing either with distinct races (elementary species) or with merely environment types. The latter view is strongly indicated by the evidence, which is not of the kind to be pertinent to this paper, but whichever of the interpretations is true, the present record will have its value. The great difference between the two samples (Lots 2 and 3) of plants which we are discussing is indicated by the weights. The plants of Lot 2 were 5 to 7 years old and had an average weight of 45.7 grms.; while of those of Lot 3 four, which were of a similar range of ages, had an average weight of only 20.2 grms. The average heights above soil were 22 and 19 cm. respectively, from which it appears that their growth rates were not connected with their transverse measurements. This is the one discrepancy which makes itself evident in a comparison of the plants of Lot 3 with irrigated ones, which may, however, be due to temperature effects, if we may assume, as seems proper, that the soil conditions need not be called into the question. That, however, a greater rainfall for 1911-1912 made itself felt more especially where it occurred, in probably greater abundance, appears to be indicated by a more rapid average growth rate for the plants of Lot 3.

The number of measurements (11 to 13) is admittedly rather too small to justify much reliance upon them, but they are given for their probable worth.

Average growth in height.

Lot No.	1911.	1912.
2	cm. 3.6	cm. 4.4
3	4.8	5.3

All these measurements are somewhat in excess of the average growth rate of 3.5 cm. per annum, as established by numerous measurements by myself (i.e.). Nevertheless, they are not excessive nor greater than observed by me for particular localities. The seedlings comprised in Lot 1, however, also show a greater amount of growth in length than is usual during years of less rainfall than occurred in 1911-12, being, for the two years, about 10 cm. against a normal of about 6 cm. (loc. cit.). The samples, the analysis of which is given below, indicate therefore a rainfall of more favourable quantity, in harmony with the testimony of Sr. Muñoz, while those of Lot 3 conform to a type of guayule which resembles the irrigated plant.

The analyses were carried out by Mr. E. H. Pound in this laboratory in the following manner. The finely ground

* F. E. Lloyd. The guayule—a rubber plant of the Chihuahuan Desert. Carn. Inst., Wash., Publ., 139, 1911.

† F. E. Lloyd. Guayule—a desert rubber plant. Pop. Sci. Mo., 41, 313-330, Oct., 1912. The Acclimatization of Guayule; India Rubber World, 1913, 47, 183, 563.

material was dried for 24 hours at 105° F. It was then extracted with acetone (6 hours) followed by petroleum ether of 60° (2 hours). The extracts were dried for one hour at 105° F. Parallel series were run. The plants of Lot 1 were entirely incorporated with the samples extracted; those of Lots 2 and 3 were divided into tops (the growth of the last two years) and stocks (the remaining basal portion). The following are the results and their averages:—

Lot 1.				
Rubber.		Resin.		
per cent.		per cent.		
1.30		12.73		
1.75		11.04		
Average 1.52.		Average 11.88		

Lot No.	Tops.		Stocks.	
	Rubber.	Resin.	Rubber.	Resin.
	per cent.	per cent.	per cent.	per cent.
2	3.47	18.70	1.20	18.50
	4.29	10.35	1.08	14.71
	—	—	1.77	10.63
	—	—	2.40	18.84
Average	3.88	17.55	1.61	17.94
3	2.68	12.06	1.46	13.05
	2.15	12.26	1.40	12.60
	2.41	12.61	1.43	12.82
	—	—	—	—
Average	2.41	12.61	1.43	12.82

NOTE.—For analyses of mature plants, see Whittelsey, J. Ind. Eng. Chem., April, 1909.

From these figures it appears that the plants of Lot 2 have about 62 per cent. more rubber in the tops and 13 per cent. in the stocks than those of Lot 3. The amount in the latter is about the same as I observed for field seedlings (exclusive of leaves) which had grown rapidly in response to a rather favourable season. In the seedlings of Lot 1 the amount is less than would be expected (namely, 1.52 per cent. against 1.80, leaves included) (Lloyd, *l.c.*), in view of the alleged considerable rainfall. But, as rain is usually local in the desert, especially on "bajadas" or footslopes, one has to admit the absence of exact information. The resin content, on the other hand, is little variable, and this fact is cited in support of a view earlier expressed that there is no connection between the occurrence of rubber and that of resin, for which view histological evidence had been given. That rubber may break down into resins is of little value as evidence that the resin in guayule is used in the building up of the rubber.

Concerning the anatomical structure of the plants in question, the same differences as between field and irrigated plants, such as I have heretofore described (*l.c.*) occur, but in smaller measure. These need not be mentioned here in detail, it sufficing to mention merely the greater development of cork, mechanical elements (sclerome) and of the tracheids, together with a reduction of medulla and medullary rays, in the plants of Lot 3, those, namely, which received the greater rainfall. Microscopical examination does not discover any discrepancy in the amount of rubber in the individual cells, except to some extent in the smallest twigs, so that we must therefore conclude that the differences in the total amount of rubber produced must be referred chiefly to the differences in the volumes of tissues which secrete rubber as compared with those which do not. That, in the case of field plants, these differences may account for a considerable difference in favour of plants of the type of Lot 2 is seen in the ratios presented by the squares on the radial dimensions of the "wood" (that is, the whole cylinder of tissue bounded by the cambium layer) and the "bark" (those tissues on the outside). This, for stems of the same sizes are:—

	Ratio Bark Wood.	
Total diameter:—	2.82	1.95
Lot 1	1.02	0.98
Lot 3	0.76	0.76

That is, in the better watered plants, the "bark" is considerably thinner.*

These ratios, however, indicate only a difference of 34 per cent. (for larger twigs) and 29 per cent. (for smaller twigs) in favour of the field plants, while the analyses show a 60 per cent. difference of rubber content for tops (which would include all the twigs of the sizes measured here together with somewhat larger ones). It is evident that an error of large size has been introduced, due as a matter of fact to ignoring the amount of cork, which is barren of rubber, and of pith, which is rich equally with the living cortex. The relative volumes of these tissues in twigs of the same diameter (about 5–6 mm.) are indicated by the following numbers, representing areas in transverse sections:—

Lot.	Pith.	Wood.	Cortex.	Cork.
2	95 19	394 522	984 788	236 380

from which it is seen that the pith is smaller and the cortex thinner, while the wood and cork are thicker. By eliminating the cork and introducing the pith into the calculation, the ratios of volume of rubber producing tissue (still ignoring the medullary rays) to "wood" turns out to be for Lot 2, 2.74 and for Lot 3, 1.55, showing a difference of 76 per cent. in favour of the plants of Lot 3. This difference would not be realised in the extractions, since, aside from the imperfections of the method, the tissues of the smaller twigs of the two lots were not, as microscopic examination revealed, equally loaded with rubber, while larger twigs were included under the heading "tops" than the size chosen for measurement, two conditions which would disturb the relative amount of rubber recoverable.

Aside from the rate of secretion, there are two ways in which the amount of rubber produced by plants is affected by water supply, namely, by altering the volumes of rubber-bearing tissues, and by affecting the total amount of secretion within them. The evidence is clear that, in speaking of the effect of soil water, this difference must be recognised. Records show that both conditions occur, either in combination, as in the plant here under discussion, or severally. The latter only has been observed in the case of latex-plants. Olson-Saffer,† and Collins and Pittier‡ have noticed that *Castilleja* produced less rubber when it had been subjected to larger amounts of water by irrigation, and Fox, quoted by Neish,§ observed that milkweed (*Asclepias syriaca* and *incarnata*) gives a higher yield of rubber when it has grown in dry soils. It is obvious that the question is one of very great practical as well as theoretical importance, quite aside from the guayule problem, the importance of which is, at present, on the wane. The rubber planter will be compelled to study this relation whenever the problems of irrigation and drainage present themselves.

Conclusion.—The determinations of rubber for two samples of feral guayule plants grown in their natural habitats under diverse conditions of soil-water, show that a relatively abundant amount of rainfall results in a plant which simulates in many ways one grown under irrigation, the likeness extending to the amount of rubber produced, and the relative volumes of bearing and non-bearing tissues. The departure from the normal, as indicated by a typical desert plant producing a maximum yield of rubber,

* The different values of this ratio for larger stems are illustrated by tables in Publ. 130, Carn. Inst. Wash., above cited.

† Year Book, 1908. Rubber Planters' Assoc., Mexico.

‡ In O. F. Cook, Bull. U.S. Dept. Agric., No. 40, Oct., 1903.

§ This Journal, 1913, 32, 72.

is such as to result in a plant which yields a distinctly less amount of rubber. Within the normal habitat of the guayule plant, therefore, the amount of rubber varies in an amount at least as great as that above indicated, namely, 62 per cent.

The amount of resin secreted appears not to be affected by the amount of soil-water, and evidence is yet lacking that rubber and resin secretion are causally related in the plant.

Such differences, which are attributable to physiological causes, are of great theoretical and practical importance.

London Section.

Meeting held at Burlington House on Monday, January 5th, 1914.

PROF. W. R. HODGKINSON IN THE CHAIR.

THE VISCOSITY OF OILS.

BY J. L. STREVS.

(Turakaki Oil Fields, New Zealand.)

Considerable work in connection with viscosity and lubrication has been carried out during the past few years chiefly with a view to determine true (or absolute) viscosity through a large range of temperature in a simple and convenient manner (Dunstan and Strevs, this J., November 30th, 1912) and more recently (Higgins, this J., June 16th, 1913) on behalf of the International Commission for the Unification of Tests on Petroleum Products.

This communication, which may be regarded as a continuation of the first paper mentioned above, does not deal with the connection between lubrication and viscosity to any further extent beyond the statement that the lubricating capacity of any oil from a purely mechanical point of view depends entirely on the viscosity. Where special circumstances attend the use of a lubricant such as in a steam cylinder, air compressor, or gas engine, the rôle played by the extraneous bodies with which it comes in contact and the affecting conditions must be taken into account, as also its chemical characteristics. Under similar circumstances oils of equal viscosity at the working temperature of a bearing, even when there are constitutional and other physical differences, possess the same coefficient of friction in the bearing (Ubbelohde, "Theory of Lubrication"). Hence the necessity for absolute viscosity temperature curves in the study of lubrication.

The first determinations made by the author in collaboration with Dr. Dunstan contained certain errors which arose unavoidably from an interpolation of Scarpa's viscosity figures for phenol, at that time the only source available from which to calculate the viscometer constant. Later figures by Dunstan and Thole (this J., Nov. 30th, 1912) resulted in a different phenol viscosity curve from which the oil-viscometer constant curve was replotted. The result was a comparatively small variation through a large range of temperature as the following logarithmic values show:—

Before correction.		After correction.	
Temp.	log. Kt.	Temp.	log. Kt.
15.5° C.	3.175	15.5° C.	3.030
100° C.	4.065	100° C.	4.000
200° C.	4.715	200° C.	4.050

Consequently previous figures for all viscosities below 88° C. (the temperature corresponding to the junction

of the uncorrected and corrected "constant" curves) are too high and those above too low.

As a check on the result a similar viscometer was recalibrated showing a corresponding curve and both instruments were used in the investigations.

Many new oils have been investigated which, with the exception of some of vegetable and animal origin, are all lubricants well known to the oil trade.

The previous viscosity curves are materially altered, especially in the high temperature region, which for some oils approximates to their actual working temperatures.

Until more is known of the actual constitution of the various lubricating oils of commerce, to what extent the viscosity is affected cannot be stated, but from analogous work on bodies of known constitution it may be generally inferred that (1) Increase of mol. wt. favours increase of Zt., e.g., rape oil (trierucin) > olive (triolein). (2) Hydroxyl formation favours increased Zt., e.g., castor oil and the blown oils. (3) Polymerisation (see 1), e.g., "Elektron" oils. (4) Solution of solid bodies in oils (e.g., "soaping") tends to a high viscosity-temperature coefficient. (5) Unsaturation tends to lower the viscosity and, broadly, the >iodine value < Zt., e.g., linseed and perilla oils less than nut or olive oil. (6) Combined high mol. wt. and conjugated doubled bonds mean a high Zt., e.g., tung oil.

Some of the figures obtained are lower than those obtained by Higgins, e.g. :—

	Strevs.	Higgins.	Temp.
Russian engine	1.40	2.45	25° C.
Olive	0.95	1.07	15° C.

This must be attributed to several causes, including difference in method of investigation and probable difference in origin of oil—long period of flow—as well as a substance of considerably lower viscosity than oils being the calibrating agent. On the other hand, the percentage rate of change of Zt. per 1° C. in the neighbourhood of 25° C.—50° C. for Russian engine oil is 5.7 against 5.6 (Higgins).

The author, in conclusion, would like to draw the attention of the International Commission for the Unification of Tests on Petroleum Products to the possibility of standardising the viscosity of an oil (or oils) by Higgins' method and using the same as calibrating liquid for the determination of the viscometer constant detailed in the above investigations. Moreover, the oil trade could use with perfect reliability and uniformity instruments thus calibrated and similar to the simple type detailed in the previous paper (this J., Nov. 30th, 1912) with all confidence in their exactitude under a guarantee certificate and constant curve drawn up by a responsible scientific authority such as the National Physical Laboratory.

Experimental Results.

Temp. ° C.	Zt.	Origin and Redwood range for commercial product.
<i>Medium spindle oil.</i>		
81°	0.008	Pennsylvania (Anglo-American). 250—280 secs. 70° F.
100°	0.0308	
150°	0.0161	
<i>Heavy engine oil.</i>		
70°	0.107	Texas. 1400 secs. 70° F.; 213 secs. 120° F.
110°	0.050	
150°	0.0233	
<i>Light gas engine oil.</i> (Dynamo oil.)		
75°	0.005	Pennsylvania (Anglo-American). 450— 500 secs. 70° F.; 80—85 secs. 140° F.
111°	0.037	
163°	0.0145	
207°	0.0086	
<i>Medium gas engine oil.</i> (Crank chamber oil.)		
70°	0.136	Pennsylvania (Anglo-American). 700— 750 secs. 70° F.
100°	0.058	
<i>Medium gas engine oil.</i>		
133°	0.0285	
150°	0.021	