EFFECT OF METEOROLOGICAL FACTORS ON THE VIRULENCE OF OIDIUM HEVEAE IN MALAYA.

BY

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INTRODUCTION.

It has now been known for some considerable time that although the rubber trees of Malaya have carried a heavy infection of the fungus causing Abnormal Leaf Fall no real epidemic of leaf-fall has yet occurred. Some districts certainly have suffered to a moderate extent, but not sufficiently to merit the adoption of the necessary control measures, nor to cause any apparent reduction in yield or vigour of the trees. On the other hand observers in the hill country districts of Java and Sumatra and the high level districts, Matale and Uva, in Ceylon report that many trees may become completely defoliated several times during the dry season when wintering takes place. It is obvious therefore that there is some natural factor which governs the activity and virulence of the fungus in Malaya. It should here be pointed out that the rubber trees in the low lying districts of Ceylon, Java and Sumatra are also only slightly affected by the fungus, and that the amount of leaf-fall in such districts is only slight although the fungus is present. The rubber trees are seriously affected by mildew only in those rubber districts at an altitude of over 1000 ft. It is unfortunate, for scientific reasons, that Malaya has no rubber growing at altitudes of above the 400 foot level. Altitude has two main effects viz:

(1) Reduction of air pressure.

(2) Reduction of temperature.

Reduction of barometric pressure is small, being only about one inch per one thousand feet, and can have little effect in itself on the growth of fungi and plants. The effect of altitude on temperature however is quite appreciable, being a reduction of approximately 3°F on the night and 5°F on the day temperatures per 1000 feet rise above sea level. Reduction of temperature therefore, may have a very great effect, more especially upon such delicate and specialised fungi as the mildew fungi.

It seems therefore that a study of the meteorological factors of Malaya and a comparison with those of Ceylon is most likely

to throw light on the Abnormal Leaf Fall problem. It is this aspect of environmental conditions which forms the basis of the following discussion.

Laboratory Experiments.

These were carried out to determine conditions for growth of the fungus *Odium Heveae*. This fungus belongs to the group of fungi known as true parasites. It has not yet been grown on dead material or on artificial media normally used for the culture in the laboratory of fungi and bacteria. It is therefore very difficult to make laboratory observations under controlled conditions, and particularly with plant tissues like those of the rubber tree, where latex exudation tends to stop up the cut ends of branches brought into the laboratory, making it almost impossible to keep such a small branch alive in a culture chamber for more than a few days. However, the results so far obtained tend to show that certain conditions, within comparatively narrow limits, may be necessary for the growth and propagation of the fungus.

For several months following the normal wintering season in the years 1930, 1931, & 1932 infected branches have been brought into the laboratory, their cut ends immersed in flasks containing tap water and kept in a cool chamber in which the humidity was fairly constant. The variation of temperature within the chamber was noted and the humidity values calculated from the wet and dry bulb thermometer readings.

By this means the following results concerning the optimum conditions for growth of the fungus were repeatedly observed during the three wintering seasons and at all times of the years during which the observations were carried out.

1. In a cold chamber at a temperature varying between 56°F and 62°F, excellent growth of the fungus occurs producing rapid spread over leaf and flowers and production of chains of 3—7 spores many of which germinated in situ as there was no wind in the chamber to carry the ripe spores away. Growth continued for seven days when the rubber leaves wilted and the fungus dried out.

The percentage Humidity within the chamber was calculated to vary between 75 and 80.6 per cent.

2. At laboratory room temperature 72°F—92°F medium growth with production of short chains of 2—3 spores took place. It was observed that very few of the spores seemed to germinate either in situ or after having fallen on to the plant surfaces. This slow growth continued for three to four days

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when wilting and drying out occurred. The percentage Humidity was calculated to vary between 50 and 93 per cent.

3. In a cold chamber at temperatures varying between 45°F and 50°F a good spread of mycelium over the leaf surfaces was first obtained, but very few conidiophores were produced; each conidiophore had one immature and more rarely a ripe spore attached. The fungus wilts and disappears from the leaf surface after four days though the rubber leaves and flowers are still in good condition and remain so for six days before the flowers drop and the leaves definitely wilt.

Several flasks containing infected rubber leaves revived to produce numerous conidiophores and conidia when placed in the warmer chamber (56°F—62°F) after two days' inactivity in the colder chamber.

The percentage Humidity of the colder chamber was calculated to vary between 73.6 and 78 per cent. This chamber was the lower section of the chamber referred to in experiment No. 1 above.

It was noted that in all the three experiments mentioned above, the youngest leaves (½—2″ long) on the branches tested, wilted within 2 to 3 days and the fungus did not develop on them. The longer half grown semi-rigid leaves remained alive longest and carried the heavier growth of fungus.

Water relationship within the leaf, i.e. cell turgidity would therefore seem to affect the rate of growth, spread and infection powers of the spores.

Experiments on growth in culture media also showed that a considerable increase both in amount and rate of germination took place in the cold chamber as compared with that of spores kept at atmospheric temperatures. At the latter temperature the development of extraneous fungi so masked the plates after two days that no ultimate figure for germination could be determined. It is of little importance, however, for the wilting of spores during the dry midday temperatures may be observed under the microscope to take place within three hours even when the spores are still attached to the parent mycelium on small portions of the floret or leaf. An indication of the difference in rate of growth and percentage germination of spores of *Oidium Heveae* in low and high temperatures may be obtained from the following figures recently obtained.

Material for inoculation was obtained by incubating Heavea inflorescences for two days in the cold chamber. A small piece of the inflorescence heavily laden with the fungus in a vigorous sporulating state, was shaken over the surface of nutrient agar

which had previously been aged for two weeks in petri dishes in the cold chamber. These plates were then incubated at the different temperatures. Plates incubated at air temperatures varying from 72 F at night to 90°F at noon and percentage humidity of 95 to 45 gave 6.9 per cent germination of spores in 24 hours and no further germination after that period when the contents of the spores collapsed. The length of germ tube produced during this period varied in length from 6 μ to 20 μ.

Plates incubated in the cold chamber at temperatures varying between 56°F and 62°F and percentage humidity of 75 to 80 gave 60.3 per cent. germination in 24 hours, while most of the remaining spores maintained their original refractive appearance. The length of germ tube produced was mostly between 110 μ and 150 μ while others were much shorter, probably having germinated later.

The plates in the cold chamber remained clean for several days and after 48 hours, 78 per cent germination was recorded. On the third day the spores and germ tubes began to wilt, the substrate being unsuitable for vegetative growth of the fungus. It would seem therefore, that under Malayan conditions an Oidium spore when freed must quickly alight upon a suitable host substrate, germinate and become attached to its host in as short a time as possible if it is to survive and multiply to produce a disease of an epidemic nature. Extreme conditions, high or low temperature, dry or wet atmosphere cannot be favourable to an epidemic spread of the disease.

From the above details of laboratory cultures on living Heveae leaves we find that for optimum growth of the fungus and optimum production and germination of spores the following conditions are necessary:—

1. A temperature not lower than 56°F and not higher than 62°F.

2. A percentage humidity of 75—80 per cent.

3. Suitable living tissues on which to grow. Observation showed that fresh young rubber leaves of 2—3 inches long, the turgidity of whose cells are such as to afford the most easy ingress of the feeding organs of the surface mycelium of the fungus are most suitable.

With the help of Meteorological records supplied by the Meteorological Officers of Malaya and Ceylon it is possible to investigate the influence which various meteorological factors have upon the growth and spread of the mildew disease of rubber trees in Ceylon and Malaya.

It has been generally understood that the amount of rainfall has some considerable influence on the incidence and spread of

this disease, but reference to the rainfall figures of the various meteorological stations in the rubber growing districts of the western territories of Malaya and of the Matale and Uva districts of Ceylon, shows that the differences in rainfall totals are not so great as would cause such a vast difference in amount of disease and leaf-fall. The manner of its falling may however have some influence in that frequent light showers have no appreciable effect on the spread of the fungus while infrequent heavy rains definitely retard the rate of growth and spread of the fungus.

Such heavy rains may influence the disease in several ways.

1. By causing the fall to the ground of any ripe spores which may have developed during the interval between storms.

2. By stimulating a far more rapid growth of the buds and young leaves of the trees, so that the leaves rapidly assume a condition of turgidity and maturity unfavourable to the penetration of the fungus.

3. Reducing the range of temperature changes, a more moderate day temperature being experienced during such weather, while in dry weather the temperature ranges are greater, and high day temperature with low night temperatures are the rule.

4. Reducing the Humidity range for a few hours following the storm. Showery weather, however, will maintain this condition over longer periods, and hence humidity more favourable to the fungus obtains.

Rainfall thus has two definite effects (a) directly on the conditions favouring the growth of the fungus and (b) on the growth of the host tissues. From field observations it is the latter which is of the greatest importance in Malaya in that the induced rapid refoliation reduces the period of time over which the leaves are susceptible to attack.

Dr. S'Jacob (1) suggests the possibility that the growth of the leaf itself thickens the cuticle and prevents any further attack from the parasite.

Unfortunately sufficiently detailed figures from badly infected estates in Ceylon are not available but from the stations at Kandy and Badulla figures are available which give a good indication of the conditions obtaining in those districts of Ceylon which suffer most from mildew viz. the uplands of Matale and Uva respectively.

Before going on to discuss the climatic conditions of the different countries it would perhaps be best to describe the incidence and effects of the disease in the districts of both Ceylon (2) and Malaya.

In the lower rubber lands of Ceylon the fungus is active during the months of February, March, and April when wintering is taking place causing a mild fall of leaf.

Other meteorological factors such as hours of sunshine per day, amount of cloud and direction and strength of wind have been carefully considered and found to give very little help in the solution of the mildew problem, though doubtless slight wind is necessary to carry the spores from leaf to leaf and tree-to-tree, but this is always available for a short period at some time of the day in nearly all the tropical climates investigated.

It is of interest to note that Malacca has considerably more windy days per month than Kuala Lumpur, and this fact may be responsible for the increase in the mildew disease in that district as compared with other districts of Malaya.

The fungus prefers the underside of the leaf and is therefore always shaded from the midday sun. An analysis of the daily hours of sunshine and of amount of cloud for Selangor, and Malacca gave no indication of possible influences on the incidence of leaf-mildew.

Humidity and Temperature.

These two meteorological factors are taken together because in small tropical countries surrounded by sea the actual vapour pressure in the atmosphere is almost constant day and night in all seasons of the year. The actual percentage humidity varies according to the temperature and the barometric pressure. In Malaya the barometer readings vary not more than 0.4 inches and this is considered to be too small to have any effect.

Percentage Humidity is defined as the actual vapour pressure represented as a percentage of the maximum vapour pressure possible within the atmosphere at a given temperature.

Malaya normally experiences a very dry midday period and a damp night period, although the water vapour pressure in the atmosphere remains more or less constant e.g. at 27—29 mb. in the rubber growing districts of Selangor. This is due to the tremendous difference between day and night temperatures viz. 91°F to 70°F. It has been shown by laboratory tests that the fungus *Oidium Heveae* is subject to rather definite limits of both temperature and humidity for its optimum growth and germination of spores.

The graphs in plate II show, that in the Malay States the temperature is at all times above what is considered the maximum limit for optimum growth of the fungus. This assumes even more importance when considered in conjunction with the figure showing the hourly changes in humidity for the respective states, which indicate that for only about one hour in the morning 9—10 a.m. and for less than two hours in the afternoon 4—6 p.m. is the humidity value suitable for optimum activity of the fungus.

Alor Star (Kedah) has the lowest rainfall of all Malayan recording stations in the months of January and February, being only 0.5 in. per month and according to preconceived ideas should be far more subject to this type of Leaf Fall than any other district of Malaya. Often the rubber trees are without leaves for several weeks during this intensely dry period yet no reports of Abnormal Leaf Fall are forthcoming. Reference to the humidity and temperature records offer the most reasonable explanation. Both these factors have a big variation in the 24 hour period with the result that temperature is always unsuited and humidity favourable to the growth of the fungus, for only one hour morning and evening viz. 8—9 a.m. and about 7—8 p.m. the actual period varying slightly according to the period of the day during which rain falls.

The report of the papers read at the conference of Empire Meteorologists in 1929 (4) contains valuable information regarding the influence of climatic factors on the virulence of parasitic fungi and insects. Many instances are given where such vigorous parasites as Bunt in Wheat, the rusts of various cultivated crops, mildew of grain and vine and many others have been rendered inactive by temporary abnormal climatic conditions. It is indicated that definite conditions of moisture and temperature are necessary to the growth and power of infection of many parasitic organisms.

It would appear from both laboratory experiments and actual field observations in Malaya that *Oidium Heveae* behaves in a similar manner. Firstly temperature and secondly atmospheric humidity are factors which are chiefly responsible for the absence of any serious epidemic of this disease in Malaya. Further after a dry period in the early part of the year the advent of rain causes a rapid refoliation of the rubber trees thereby enabling the leaves to outpace the spread of the disease. These three factors go far to ensure that the rubber trees of Malaya remain comparatively free from abnormal leaf-fall.

The question may reasonably be asked why has this disease become so prominent in rubber growing countries during the past three or four years? Considerable difficulty is met with in answering and explaining this question. It might here be pointed out that several planters in the Malacca district who have had long experience of rubber in this country recall that in 1911—13 a similar mysterious leaf fall occurred but that it disappeared in later years. Unfortunately the writer has failed to find any authentic records of a disease of the young leaves in these years, but from the descriptions given and the fact that the planters

themselves felt sure of the similarity, it is probable that this disease was also caused by the same fungus.

Further the meteorologists tell us that annual weather changes show an approximate cycle of either 17 years, or more closely, a cycle of 35 years. It is therefore possible that the slight climatic differences from normal of the years 1928-32 correspond to those obtaining in 1911—13. The disease would not be so obvious in those early years the trees being then much younger and the soils comparatively more fertile, thus ensuring a quicker development of the young leaves.

Alternatively it must be considered that as there are many species of the Oidium fungi existing on other host plants in this part of the tropics it is possible that following the clearing up of such vast areas of jungle a type of fungus parasitic to rubber has been developed along natural lines. If this is so we must be prepared for more trouble from this disease in future years. It is, however, comforting to know that climatic conditions, particularly those of temperature and humidity are not suited to the optimum activity of fungi of this type. Consequently the rubber trees of Malaya may have practical freedom from the abnormal leaf fall caused by the fungus *Oidium Heveae*, unless, perchance, the commercial value of rubber should soon rise to such heights as would make it profitable to plant rubber on the precipitous slopes of Malayan mountains. Here, the temperature might be low enough to retard the refoliation of the trees following wintering, and favour the germination, growth and parasitism of the fungus to such an extent as to cause an epidemic of abnormal leaf fall. If leaf fall happens to occur in such areas and the yield is seriously lowered then sulphur dusting by means of power dusters will have to be resorted to as is the case in the uplands of Java, Sumatra and Ceylon.

SUMMARY.

The meteorological conditions obtaining in the eastern rubber growing districts are described and compared.

The optimum conditions for growth and germination of spores of the fungus *Oidium Heveae* as determined in the laboratory are given, and taken as a basis upon which the influence of meteorological factors may affect the virulence of the fungus on rubber trees.

It has been shown that these optimum conditions are that suitable young plant tissues are available, that rainfall is not too heavy, that the humidity of the atmosphere is in the neighbourhood of 75 per cent to 80 per cent and that the atmospheric temperature is about 60°F.

It is then shewn that the climates of the high level rubber growing districts of Ceylon, Java and Sumatra more nearly approach these optimum conditions than does that of Malaya, where rubber is grown only at low altitudes and remains comparatively free from the disease.

References.

1. S' Jacob Dr. J. C. "Microscopical investigations on Heveae Mildew." *Archief voor de Rubberculture.* April 1930.
2. Murray, R. K. S. "The Control of Oidium Leaf-Disease" *Rubber Research Scheme Ceylon, Quarterly* Vol. **7**, part. 4.
3. Murray, R. K. S. "Diseases of Rubber in Ceylon" 1930" *Rubber Research Scheme Ceylon, Quarterly,* Vol. **8**, part 1.
4. Conference of Empire Meteorologists 1929,*Agricultural Section.* **II.**

Description of Plates.

Plate 1. The upper diagram shows the monthly rainfall in inches at Kuala Lumpur for the years 1927 to 1932 while below is a diagrammatic representation of the incidence of the mildew disease in Malaya. Note the reduction in disease following the March or April rains. Note also the peak year for the disease, 1931, when only moderate rainfall occurred during the early months of the year.

Plate 2. The upper graph represents the hourly changes in Percentage Humidity for a March day in Kuala Lumpur, Malacca and at Badulla in Ceylon. Note the close similarity between Ceylon and Malacca conditions, and their approach to the optimum range, while Kuala Lumpur enjoys an extremely dry period during the middle of the day.

The lower graph gives the hourly changes in temperature for the same stations. Note that both Malacca and Kuala Lumpur are well above the optimum range for growth of the mildew fungus, while Ceylon (Badulla) very closely approaches that optimum from 9. p.m. to 9. a.m.

The shaded zone represents the range for optimum growth of the fungus in each of these graphs.

Kuala Lumpur. F.M.S., November, 1932.

PLATE 1.

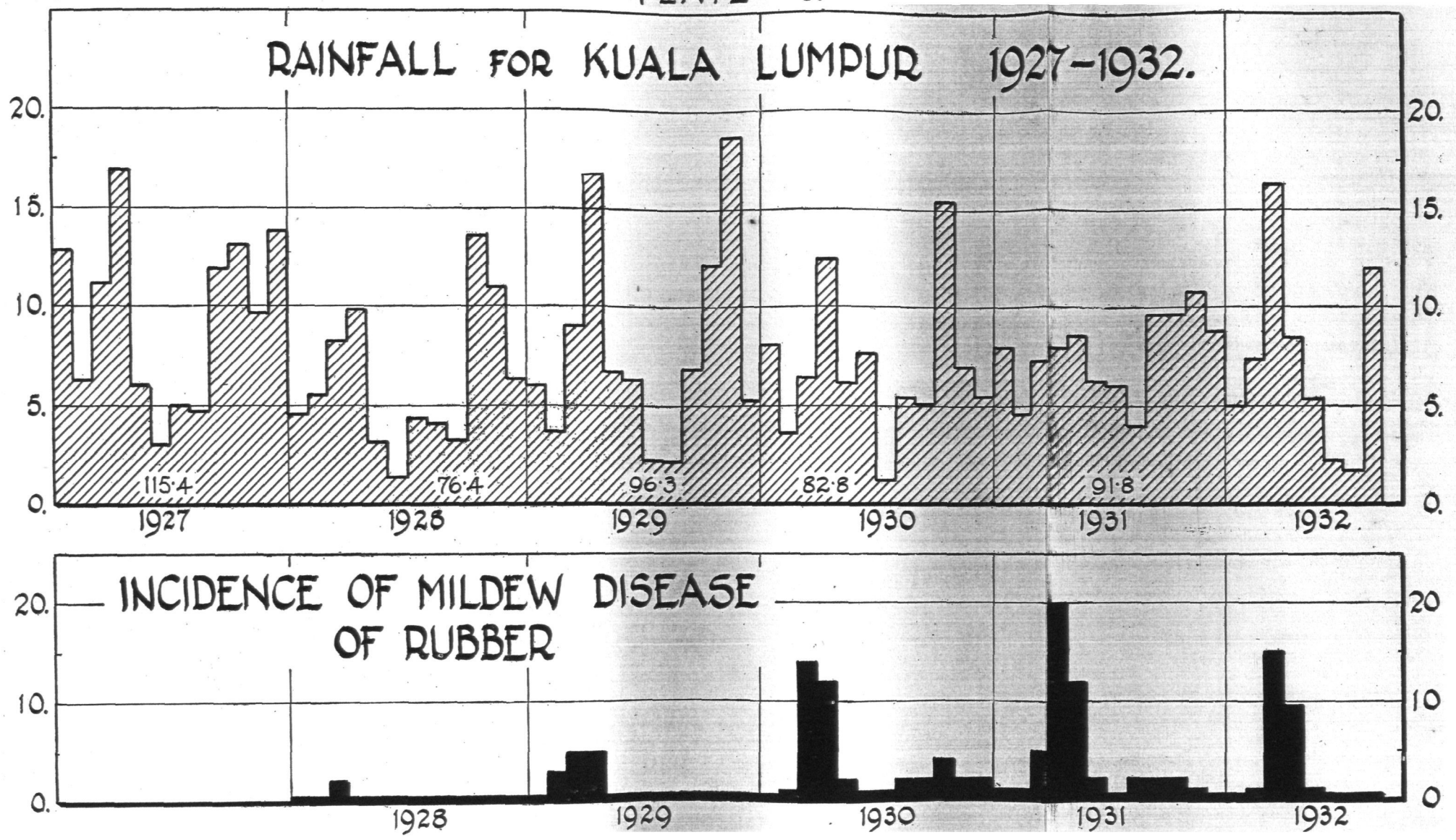
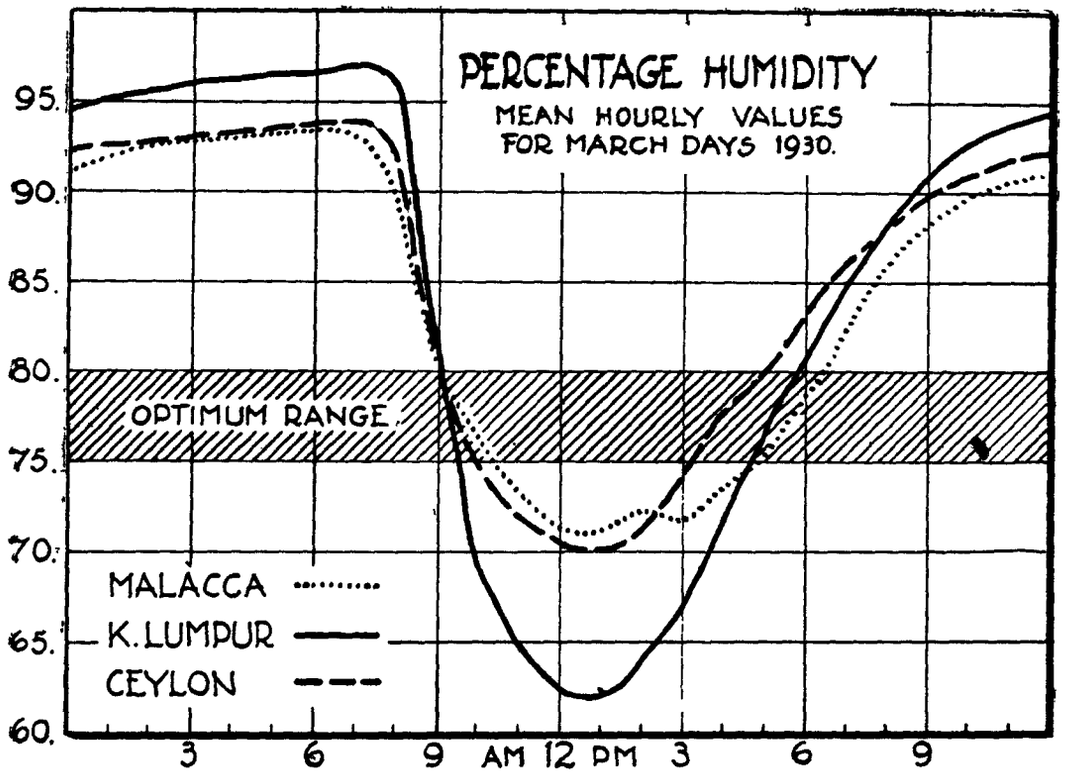
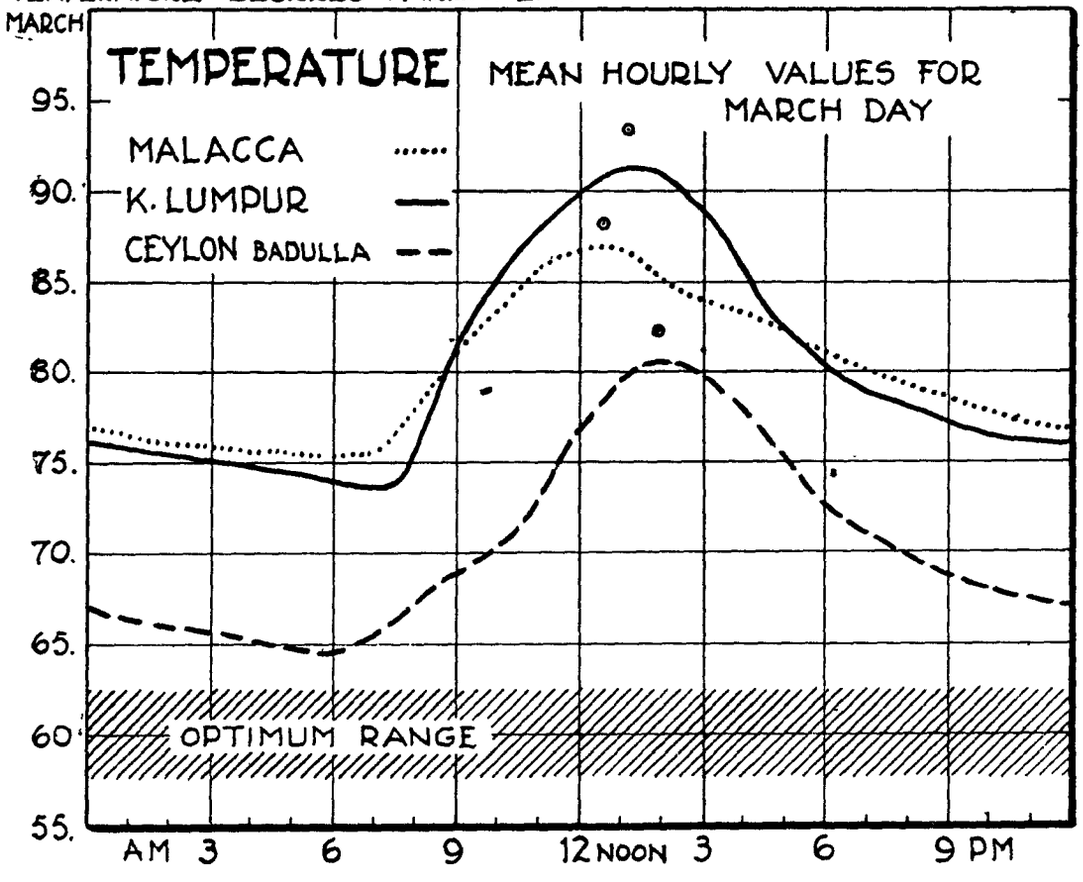

RAINFALL FOR KUALA LUMPUR 1927-1932.
20.
15.
10.
5.
0.
115·4
76·4
96·3
82·8
91·8
1927
1928
1929
1930
1931
1932.
INCIDENCE OF MILDEW DISEASE OF RUBBER
20.
10.
0.
20
10
0
1928
1929
1930
1931
1932

PLATE 2.



TEMPERATURE DEGREES FARENHEIT.