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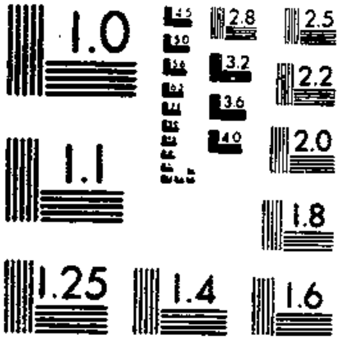

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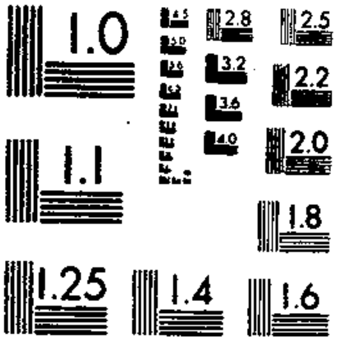

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Target Leaf Spot of the Hevea Rubbertree in Relation to Host Development, Infection, Defoliation, and Control[1]

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CONTENTS

INTRODUCTION

The target leaf spot disease (caused by *Pellicularia filamentosa* (Pat.) Rogers (*17*))[4] of the hevea rubbertree (*Hevea brasiliensis* (Willd. ex A. Juss.) Muell. Arg.) (*15*) and of other species of

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[2] In cooperation with the Ministry of Agriculture of Peru and the Peruvian Amazonas Corp., which financed the Peruvian contribution to the rubber project at the Estacion Experimental Agricola en Tingo Maria, Tingo Maria, Peru.

[3] Grateful acknowledgments are made to B. S. Crandall, V. E. Iverson, and C. W. Swingle, all former staff members assigned by the Office of Foreign Agricultural Relations to the Tingo Maria station, for advice and criticism during the course of the work, to Ingeniero M. Lescano Alva and personnel of the Rubber Section of the station for wholehearted assistance, and to the directors of the station for the facilities extended; to personnel of the Biometrical Unit, Bureau of Plant Industry, Soils, and Agricultural Engineering, for generous cooperation in the analysis and presentation of the statistical data; and to the staff of the Division of Rubber Plant Investigations for counsel and assistance during the preparation of this report.

[4] Italic numbers in parentheses refer to Literature Cited, p. 33.

this genus was apparently unrecognized, though collected (*17*), prior to the initiation in 1940 of the Cooperative Rubber Program between the United States and each of several Central and South American republics. With the increased attention to this crop in tropical America, numerous mycological collections were made by survey parties and at field stations. A recent examination of herbarium specimens (*17*) placed the earliest known occurrence at Isapuri, Bolivia, where it was collected in 1901 on a putative hybrid of *H. brasiliensis* × *H. guianensis* Aubl. var. *lutea* (Spruce ex Benth.) Ducke & Schultes. The next collection was made on *H. brasiliensis* at Lancetilla, Honduras, in May 1941. It was found later in the same year at Belém, Brazil; at Iquitos and Tingo Maria, Peru, in 1942; near Leticia, Colombia,[5] in 1946; and in Turrialba, Costa Rica, in 1947 (*5*).

Deslandes (*7*) first described target spot in 1944 on the basis of observations at Belém and Belterra, Brazil, in 1943 and stated that cases had been reported elsewhere in the Amazon Valley. It was identified also in Porto Velho on several clones in 1948 during the course of the present work. Deslandes found the disease on *Hevea benthamiana* Muell. Arg., *H. guianensis* Aubl., *H. pauciflora* (Spruce ex Benth.) Muell. Arg., and *H. spruceana* (Benth.) Muell. Arg., as well as on *H. brasiliensis*. The cultural characteristics and morphology of the fungus and infection studies made under greenhouse conditions were published by Kotila (*8*) in 1945. Lorenz (*12*) reported on the economic importance and occurrence of the disease in Peru, indicating its geographic range throughout the eastern lowlands of that country, and added *H. guianensis* var. *lutea* to the host range. A further brief report on the target spot investigations in Peru was made in 1949 (*2*). Infection studies by Crandall (*6*) and others (*5*) have shown that the same fungus from a number of diverse tropical crops may infect hevea. Some of these are of special interest, as they may be used for intercropping rubbertrees or as cover crops. The perfect stage of the organism has been produced in culture. Studies on the production and discharge of basidiospores (*3*) corroborate the opinions expressed by Kotila (*8*) and Lorenz (*12*) that basidiospores are the major factor in dissemination of the disease.

Target spot first became severe in Peru in 1944, and by the rainy season of 1945–46 it had assumed epidemic proportions in nearly all the centers of the Peruvian Cooperative Rubber Project: Tingo Maria; Plantation Yurac No. 1, Aguaytia; Plantation Yurimaguas No. 2, Santa Maria; Punchana Nursery, Iquitos; and Fundo Iberia, Madre de Dios. When uncontrolled, the disease has continued to be serious during the rainy season, resulting in severe infection and defoliation that retard the growth and reduce the vigor of young plants. It is of greatest importance as a nursery disease, where it limits or prevents the successful grafting of seedling stocks and reduces the quantity of suitable budwood in clone-multiplication gardens. When seedlings develop to the first flush stage in seedbeds prior to transplanting the disease can cause severe damage and may assume the appearance of a typical web blight. Target spot also may

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[5] Letter dated November 29, 1946, from M. H. Langford to J. B. Carpenter.

retard the growth of field-planted trees until they have established a crown of foliage and have undergone several annual leaf changes.

The work here reported was done during the period from May 1946 to September 1949. Although control measures were the first phase, the host- and disease-development investigations are presented first to emphasize their influence on the choice and effectiveness of control measures against target spot.

HOST DEVELOPMENT

Host-development studies were made along with the pathological work as the need for specific information on growth arose. The investigations centered about the development of the "flush," as the successive segments of the rubber shoot or branch are commonly termed (fig. 1). The principal objectives were to determine the time required for the unfolding, expansion, and maturing of the leaves and the frequency of flush formation under favorable growing conditions. This information was useful both in the development of control measures and the interpretation of their results, and as a basis for the disease-development studies.

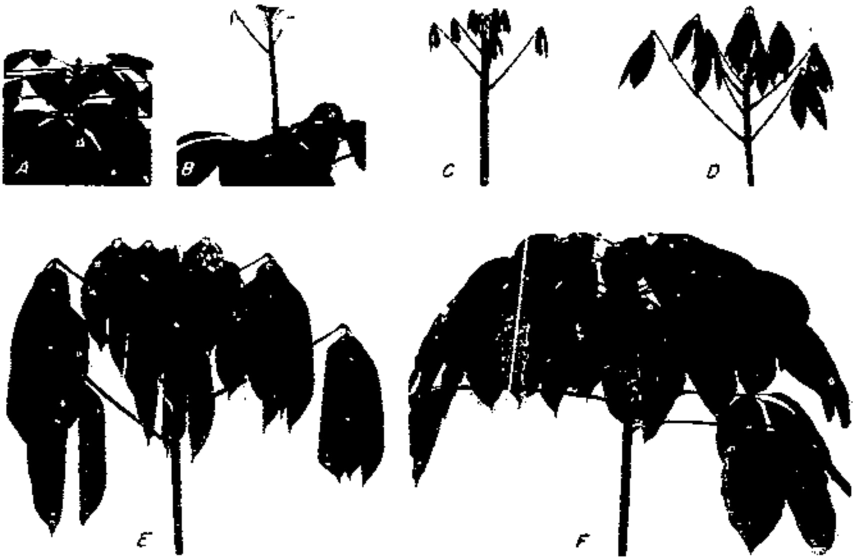

FIGURE 1.—Development of the flush of hevea rubbertree on young vigorous plants, with the successive stages represented by 6 typical individuals photographed on approximately the same scale. The period between bud burst and raising of the leaves to the mature position involves about 5 weeks, followed by another period of about 2 weeks before a new flush may be formed. Several of the important stages are shown, with their approximate ages expressed as days after bud burst: *A*, Emergence of the growing point, 2 to 4 days; *B*, elongation of the stem and unfolding of the first leaf, 6 to 9 days; *C*, elongation continuing with nearly all leaves unfolded, 11 to 14 days; *D*, intermediate stage of leaf expansion, 14 to 17 days; *E*, leaf expansion completed, with the leaves just ready to raise themselves, 27 to 30 days (note the change in the curvature of the petiolule between *D* and *E*); *F*, mature leaf position, 31 to 35 days.

The characteristic growth habit of a vigorous young rubber plant (*16*) may be summarized as follows: It usually remains unbranched more than a year and grows continuously for 2 or 3 years, producing a series of flushes by periodic development of the terminal and lateral buds. The flush is composed of a more or less elongated stem, terminating in a progressively more compact spiral of digitately trifoliate leaves (fig. 1, *F*). Although some variation may occur in the number of leaflets, it is negligible in the commercial clones. Depending on the age and vigor of the plant, the flush may be from a few centimeters to nearly 1 meter long and bear from several to 30 or more leaves.

The young leaf blades are reflexed within a few days after separating from the growing point (fig. 1, *B* to *E*) and remain pendent until fully expanded, afterwards becoming reclinate (fig. 1, *F*). The pendent leaflets are so disposed that each bounds one side of a triangular interspace, with the ventral surfaces facing outwards. This position and their glossy surfaces make the young leaves difficult to wet with fungicides. Older leaves are more easily wet.

METHODS AND MATERIALS

The plant material usually consisted of vigorous, unbranched shoots of clones GA 1279 and FB 54[6] growing in the multiplication gardens. Foliage-development studies were based on measurements of individual leaflets rather than on the whole leaf, as the leaflet is the simplest measurable unit. The uniform number of leaflets permits expression of the data in terms of whole leaves where this is desirable. A leaf was considered to be unfolded and measurable (fig. 1, *B*, lowest leaf) when it had separated from the growing point and the leaflets had been reflexed into the typically pendent position.

Investigations into the time required for the flush to unfold and expand its foliage were made during the period August to December 1946. A new series of flushes was tagged for each clone at the beginning of every month until the severity of target spot stopped the work. In each series measurements were made on 12 uniform flushes of each clone, selected when the shoots were not more than 1 cm. long (fig. 1, *A*). These provided 10 plants for calculations. The two extras (*E*–1 and *E*–2) replaced when necessary the first and second damaged shoots, respectively, among those numbered 1 to 10. Infrequently, losses in excess of 2 plants resulted in fewer samples. Observations and measurements were made at 3- to 4-day intervals for about 6 weeks on each series.

Measurements made in August on the length and breadth of the lamina of each leaflet of the first leaf showed that expansion in both dimensions was simultaneous. Thereafter, only length measurements were made. Occasionally, the second or third leaf was substituted for an atypical first leaf. The dates on which individual plants unfolded their first leaf varied somewhat in each series for the two clones. Therefore, the plants in each series were grouped by

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[6] Clone GA 1279 is a high-yielding Eastern panel clone, and FB 54 is a top-working clone resistant to South American leaf blight. Both have been used extensively in tropical America.

the date of the initial unfolding and treated as averages in subsequent calculations.

All three leaflets of the first leaf on each flush were measured and the measurements averaged for each reading. The individual or group averages were plotted on large sheets of graph paper, according to the dates of measurement. The 3-day points were read from these curves, weighted according to the number of samples represented, and averaged to give a single curve for each clone in every monthly series. The results on the rate of unfolding of the leaves were treated similarly.

In December 1948 and January 1949 a more detailed study of flush development was made, modifying the methods outlined. Twelve uniform flushes of clone GA 1279 were selected at the stage shown in figure 1, *B*, so that all would develop concurrently. Length measurements were made daily at about the same hour on the central leaflet of the first, fifth, tenth, fifteenth, and terminal leaves until elongation ceased. At maturity, length measurements were made on the central leaflet of every leaf in each flush and the relationship between relative position and size was noted. Calculations were based on 10 plants out of 12, as already described.

As the relationship between position and size seemed odd, similar measurements were made of every leaf on each of 25 recently matured flushes for 3 clones, in order to check the preliminary data.

The relative rates of leaf elongation during day and night were investigated also. Length measurements were made twice daily at 6 a. m. and 6 p. m. on the central leaflet of each of 24 leaves on young potted plants growing in a glass-roofed shelter, described in the section on infection studies. Although the leaves were smaller than those found on older plants, the development of the flushes was typical.

The statistical calculations in this section and the section on defoliation were made by the Biometrical Unit, Bureau of Plant Industry, Soils, and Agricultural Engineering.

RESULTS

The preliminary data that led to the use of the rate of elongation of the leaflet, and especially the central leaflet, as an index to leaf growth are presented, as similar problems of measurement arise frequently in pathological work.

Length and breadth measurements on expanding leaflets of clones GA 1279 and FB 54 are given in figure 2. Least significant difference (L.S.D.), or smallest difference required for significance between means at indicated levels, is shown for this figure and elsewhere as recorded. Up to the fifteenth day after unfolding, both length and breadth showed increases significant at the 5-percent level and usually at the 1-percent level. The ratio of breadth to length gradually increased by about 7 percent. The increase in ratio was consistent, although the analysis showed differences that were statistically significant only between the extreme values. The increments between the fifth and eighteenth days represent a typical leveling-off of the growth curves. The correlation coefficient of 3-day increases between breadth and length was 0.90. The coefficient of

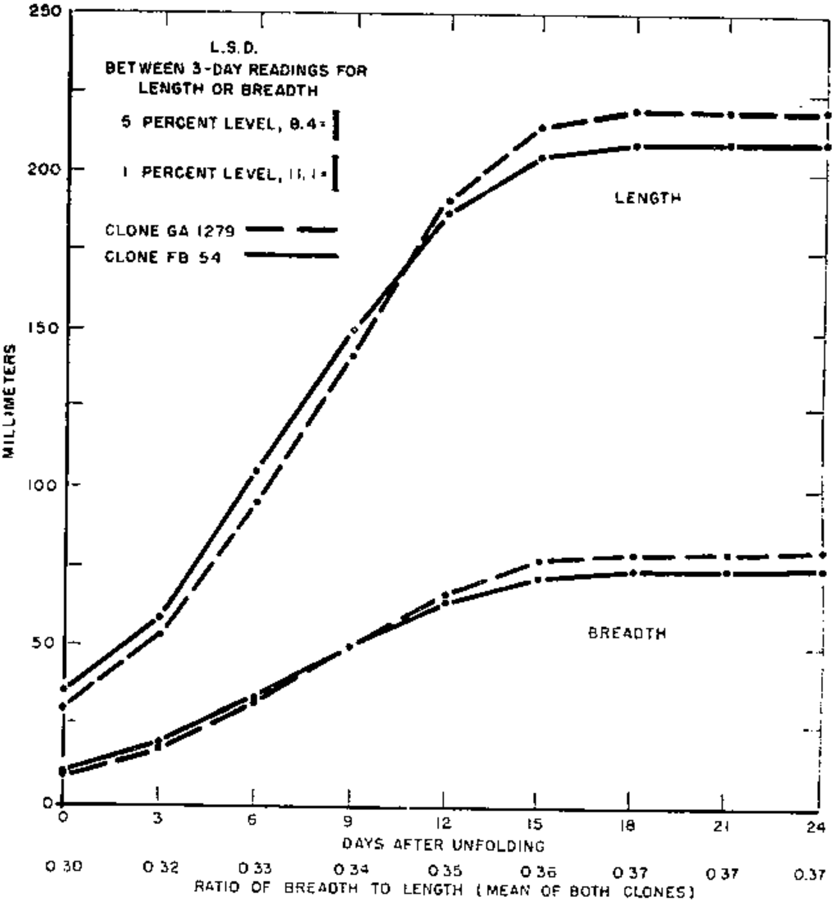


FIGURE 2.—Growth in length and breadth of the leaflets of the first leaf on vigorous young flushes of two hevea clones.

determination ($r^2 \times 100$) was 82 percent, which indicates that 82 percent of the variation in length is associated with the variation in breadth, or vice versa.

Although either length or breadth might serve as an index to the rate of expansion, the length measurements are more accurately and easily made, as the midrib is a constant reference point and the longer axis. Conversely, the position of the widest point is variable and must be sought at each reading.

The relative lengths of the central and lateral leaflets for these clones, based on measurements of the first leaf, are presented in figure 3. Elongation of the leaflets was uniform. The central leaflet was consistently longer than the laterals, and, although the differences were small, they were observable and, on fully expanded leaves, are significant at the 5-percent level for both clones. This length relationship appears to be generally applicable to all rubber-

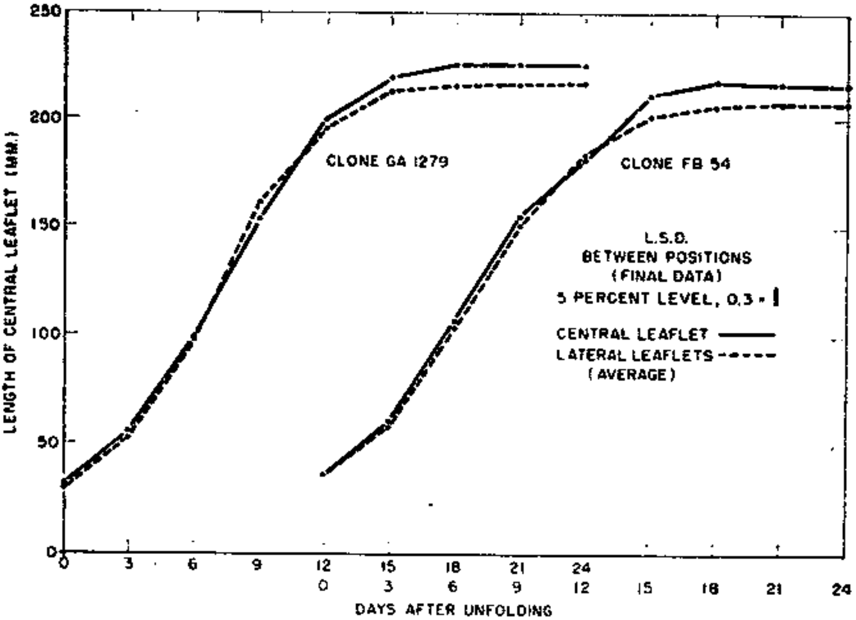


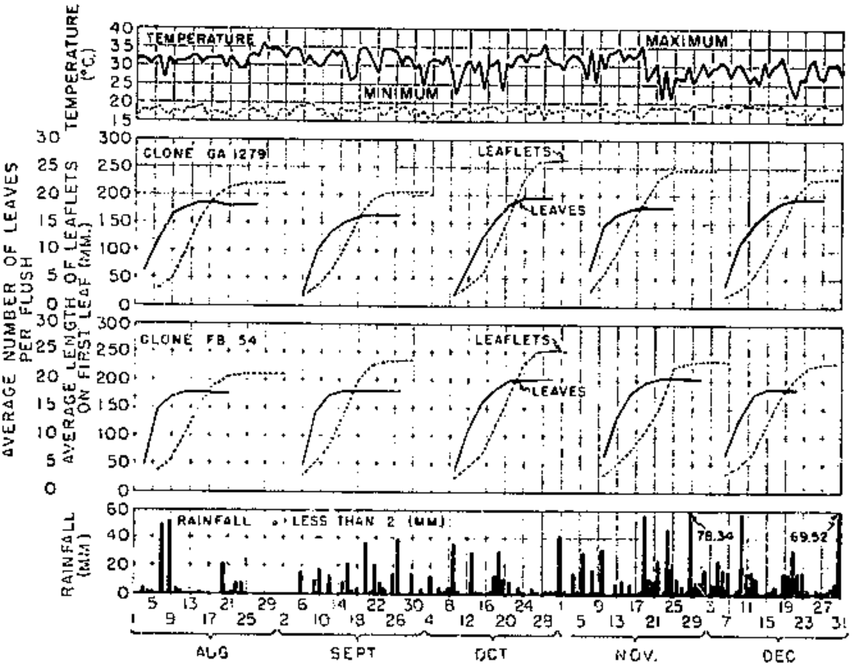
FIGURE 3.—Development of the central and lateral leaflets of the first leaf on vigorous flushes of two hevea clones.

tree leaves, although the differences are undoubtedly exaggerated in foliage on vigorous young plants.

Because of this and the ease of designating its position, elongation of the central leaflet served as a suitable index to the growth of the whole leaf and was used in the later experiments.

Results of the 5-month study on flush development appear in figure 4, which presents comparative results for clones GA 1279 and FB 54 during the period from August to December, inclusive. Rainfall and temperature records are given to illustrate the changes that occur as the seasons progress from August—a month with bright days, high temperature, low rainfall, and short day length—to December—a month marked by cloudy days, more moderate temperature, high rainfall, and long day length.

Unfolding of the leaves from the growing point was rapid, occurring within a period of 8 to 12 days. The differences between months or clones in relation to the number of leaves per flush were not significant. Leaf expansion, expressed as the rate of elongation of the first leaf, was also rapid, requiring 16 to 21 days. Daily increments of 2 cm. or more were common during the most active period of growth. There were significant differences at the 5-percent level in final leaf length among the several months, but there were no differences between clones. The leaves formed in October were significantly larger than those for either August or December. The leaves formed in September or November were usually of intermediate size.



L. S. D. between monthly series, length of leaflets on first leaf, based on final data { 5 percent level, [illegible]; 1 percent level, [illegible]

L. S. D. between monthly series, number of leaves per flush, based on final data { None

FIGURE 4.—Unfolding and elongation of the first leaf on vigorous flushes of two hevea clones over a period of five consecutive months, with rainfall and temperature records.

Observation indicates that the relationship between the rates of unfolding and expansion are generally applicable, regardless of other clonal differences.

The more detailed study of flush development (fig. 5) indicates that the time required for leaf expansion is uniform, regardless of position in the flush or size of leaf, with perhaps a day's difference between the larger and smaller leaves. However, there were substantial differences among the rates at which elongation occurred, with a markedly smaller daily increment and ultimate size in the upper leaves. There were significant differences in final length at both the 5- and 1-percent levels among the various leaf positions. The fifth leaf was much longer than either the first or tenth, which were not significantly different. The differences between the tenth, fifteenth, and last positions were significant.

Unfolding of the leaves was typical (fig. 4) and occurred within a period of 10 days.

The relationship between position and size of leaf seemed odd, because the first leaf was smaller than those immediately above it. To check the validity of these limited data, further measurements were made on 25 recently matured flushes of each of 3 clones,

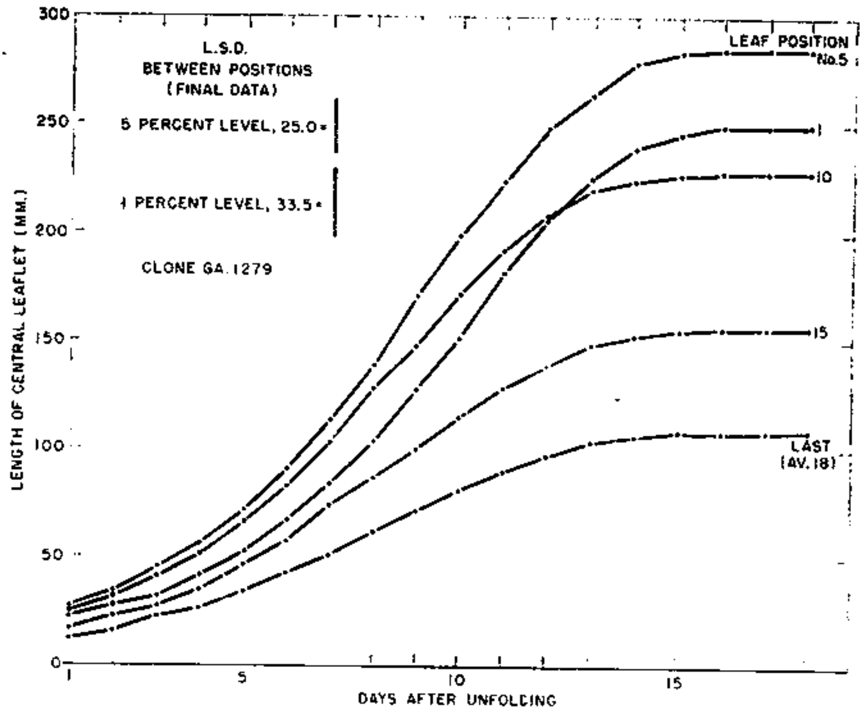
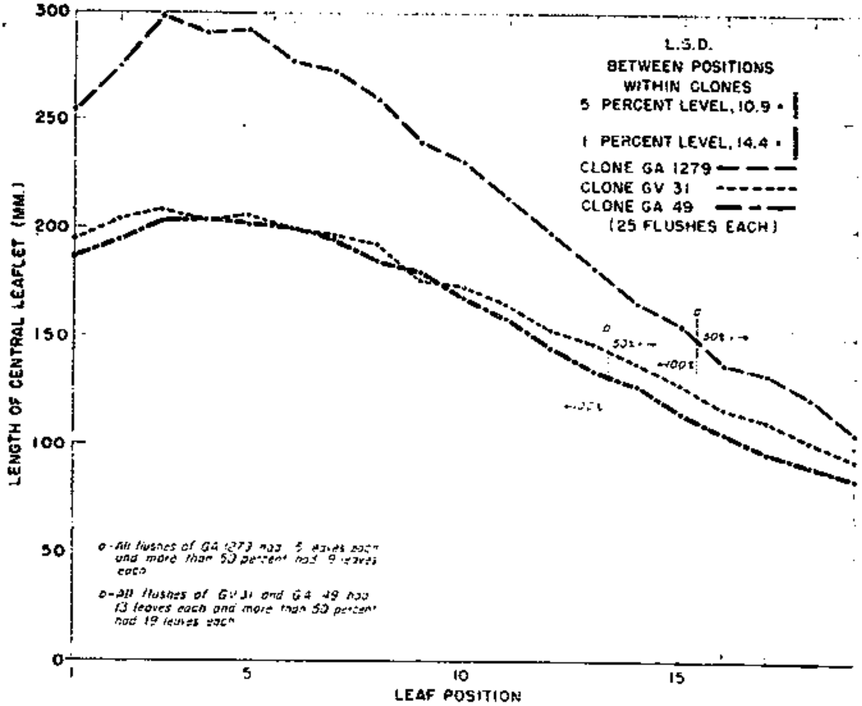


FIGURE 5.—Relationship of leaf position in the flush to the rate of elongation, and size expressed as length, for hevea clone GA 1279.

GA 49, GA 1279, and GV 31. The data were plotted for all leaf positions represented by 50 percent or more of the samples. The results (fig. 6) indicate that this relationship is not unique for clone GA 1279 but is probably general among rubbertree clones. The effect is not readily observed, as the differences in leaf length appear to be compensated for by greater petiole length. The quantitative differences in leaf size for any position are due to clonal characteristics. Young plants of GA 1279 have long leaves, whereas clones GA 49 and GV 31 have shorter and relatively broad leaves.

An analysis of variance in the first 13 leaf positions, where 100 percent of the samples were available, indicates that there are many differences significant at the 5-percent level between positions within clones. From the second to the sixth positions there were few differences. Beginning with the sixth leaf, there was a rapid and consistent decrease in leaf size. Subsequent to the seventh position, there were significant differences even at the 1-percent level.

Data on the relative rate of elongation of the leaves during the day and night are given in figure 7. Although elongation was continuous, the results suggest that the daytime increments are greater in the earlier part of the period and that the night increments are greater in the latter part of the period. The total average increment in length during the day was 58 mm. and during the night 59 mm. over a period of 17 days.



a—All flushes of GA 1279 had 5 leaves each and more than 50 percent had 9 leaves each

b—All flushes of GV 31 and GA 49 had 13 leaves each and more than 50 percent had 19 leaves each

Figure 6.—Relationship between position in the flush and leaf size for three hevea clones.

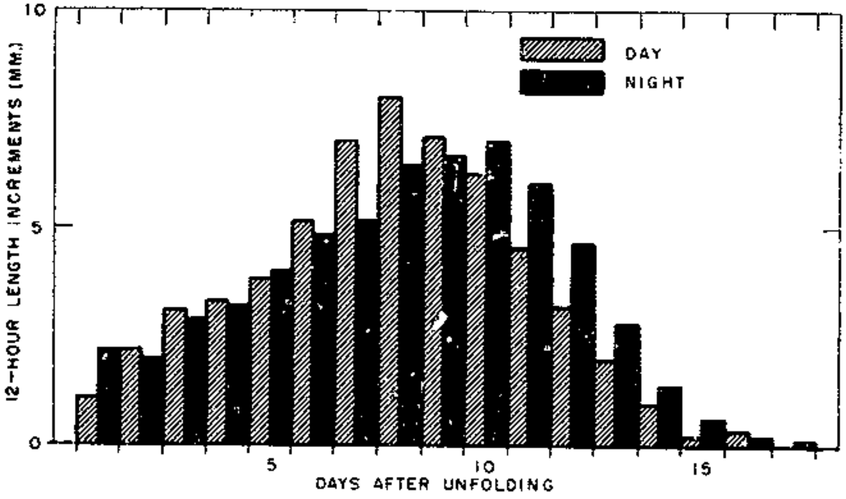


Figure 7.—Elongation of the leaves on potted hevea seedlings during the day (6 a. m. to 6 p. m.) and night (6 p. m. to 6 a. m.), expressed as the average daily increment for each 12-hour period.

INFECTION STUDIES

The aspects of infection studied were: (1) Germination of the basidiospores; (2) time required for infection to occur on susceptible leaves; (3) period during which the leaves were susceptible; and (4) length of the incubation period between exposure to infection and appearance of symptoms.

METHODS AND MATERIALS

Germination studies were made with freshly discharged basidiospores from infected leaves obtained by the method used in sporulation studies (*3*). The germination tests were made at night in order to obtain abundant spores. Clean glass slides were exposed in the spore-discharge chambers for 15 and 30 minutes in the first and second trials, respectively. Then they were removed and 3 drops of rain water were spread over their surfaces. The slides were incubated in glass damp chambers, either in the dark or in light from a 100-watt light approximately 18 inches above the chambers. A set of six slides was used for each time interval—1-, 2-, 3-, 4-, and 6-hour—and for both light and dark conditions. The time interval included the period of exposure to spore discharge. The temperatures were moderate, ranging from 23° to 26° C., in the two trials. At appropriate intervals, 1 or 2 drops of cotton blue in lactophenol was added to each slide to kill and stain the spores and a 25 by 50 mm. cover glass placed thereon. The preparations were examined microscopically the following day.

Small potted seedlings were used for the infection trials. These were maintained in an open-sided glasshouse, where temperature and humidity were essentially equal to those prevailing outdoors. The glass was not opaqued, because the roof structure was somewhat heavier than in commercial-type houses and provided sufficient moving shade, in conjunction with ample ventilation, to prevent heat injury. This shelter permitted utilization of the conditions of light, humidity, and temperature that prevailed during the rainy season without the complications introduced by rain and dew.

Inoculations were made in a small infection chamber where the humidity was maintained at or near saturation by a wet cloth tent lining and by spraying the plants when placed inside. During prolonged tests, the outside of the tent and inner wall of the chamber were sprayed occasionally. The walls of the chamber were of cellophane-wire screening that permitted the entrance of diffuse daylight, though the chamber was shaded permanently. Inoculations were always made at night in natural darkness, beginning about 8 p. m., in order to take advantage of basidiospores discharged from damp, heavily infected leaves supported over the plants on a wire rack.

The chamber was prepared for use at least by midday whenever a new series of tests was to be made, so that high humidity could be established and the fungus encouraged to sporulate abundantly by early evening (*3*). The same charge of leaves for producing inoculum could be used 3 or 4 days without renewal, taking care only to keep the leaves damp on the upper surface. Direct wetting of the lower, sporulating surface was avoided. Excessive aerial mycelium was collapsed daily by airing the chamber for a few minutes.

Plants removed from the chamber were incubated in the glasshouse without further moistening of the leaves, which dried quickly. Although small numbers of plants were used in a given test—usually 7 to 10 with 2 leaves each—every test was repeated several times and all gave consistent results.

RESULTS

Basidiospores germinated equally well in either darkness or in artificial light. Germination was somewhat erratic, possibly because only rain water was used as the germination medium. Limited trials showed some germination within 2 hours after discharge. At the 4- and 6-hour intervals it was far advanced, many germ tubes being twice as long as the spore.

Infection was established rapidly (table 1), sometimes following a 3-hour exposure to inoculum. A 6-hour exposure led to 50-percent infection of susceptible leaves, and the 12-, 18-, and 23-hour expo-

TABLE 1.—*Number of leaves of different ages infected after varying periods of exposure to discharged basidiospores of Pellicularia filamentosa in an infection chamber*

Age of leaf[1] (days)	Leaves affected after exposure in infection chamber for—									
	3 hours		6 hours		12 hours		18 hours		23 hours	
	Inoculated	Infected	Inoculated	Infected	Inoculated	Infected	Inoculated	Infected	Inoculated	Infected
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
0	11	0	12	5	4	4	9	9	21	24
1	31	0	16	13	13	13	17	17	22	22
2	13	6	13	12	6	6	10	10	4	4
3	6	3	6	6	5	5	3	3	9	9
4	3	2	1	1	1	1	2	2	10	9

[1] Age of leaf was dated from the time the leaf had unfolded and the leaflets were fully reflexed (fig. 1, *B*). Class 0 included the leaves separated from the growing point, but without the leaflets reflexed.

TABLE 2.—*Number of leaves infected by target spot in relation to age at time of inoculation and incubation period between infection and appearance of lesions. Plants were exposed for about 23 hours in the infection chamber*

Age of leaf[1] (days)	Leaves		Leaves infected in incubation periods of								
	Inoculated	Infected	5 days	6 days	7 days	8 days	9 days	10 days	11 days	12 days	13 days
	Number	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*	*Number*
0	24	21		1	1	1	4	1	9	3	1
1	22	22		2	8	6	2	3	1		
2	4	4		1	2	1					
3	9	9		2	4	3					
4	10	9	1	6	1	1					
5	13	11		5	3	1	1			1	
6	18	13		9	4						
7	17	3		2						1	
8	8	2		2							
9	7	1			1						
10	2	1			1						
12	2	0									

[1] Age of leaf was dated from the time the leaf had unfolded and the leaflets were fully reflexed (fig. 1, *B*). Class 0 included the leaves separated from the growing point, but without the leaflets reflexed.

sures were followed by almost 100-percent infection. The lesions were so numerous at the longer exposures that the affected leaves often withered before leaf expansion was completed.

The leaves were susceptible for only about 1 week after unfolding (table 2). All unfolded leaves from 1 day to 4 days old were infected and thereafter the percentage of leaves infected decreased rapidly, with no infections on leaves more than 10 days old. Thus, the period of greatest susceptibility occurred before the most active period of leaf expansion began (fig. 5).

The incubation period between infection and appearance of lesions was commonly from 6 to 8 days on leaves 1 to 8 days old (table 2). On leaves less than 1 day old (fig. 1, *B*, second leaf, et seq.), the incubation period was usually lengthened to 8 to 11 days.

EXPERIMENTAL DEFOLIATION

Target spot weakens the plant principally, if not solely, through reduction of the effective leaf area by infection and leaf fall, both of which may be considered as defoliation. No other plant parts are known to be attacked, and no evidence of toxic action by the parasite has been observed. Because defoliation is thus uncomplicated by accessory effects, the disease was simulated in a study of the influence of experimental defoliation on the growth of young seedling rubber plants.

METHODS AND MATERIALS

There were six treatments, based on controlled defoliation of young seedlings, expressed as 0, 20, 40, 60, 80, and 100 percent of defoliation. The experiment was begun with 2- to 3-month-old seedlings, planted as germinated seeds at a spacing of 30 by 45 cm. in nursery beds. Planting losses and removal of obviously atypical plants reduced the original stand by about 30 percent. Two parcels of land, about 30 meters apart, were used in order to take advantage of a large number of plants. Parcel A was level, and the plants were about 2 months old; parcel B had a gentle slope, and the plants were about 3 months old. Both areas had borne nursery plantings previously and had been cover-cropped with *Crotalaria spectabilis* Roth for several months just prior to replanting for this experiment. No fertilizers were applied subsequent to the cover crop.

Each parcel contained five 12-tree replications of every treatment except the control, treatment 1, which was replicated 10 times in parcel A and 8 times in parcel B. The use of 12 numbered plants per plot allowed for the loss of 20 percent of the plants through damage or pronounced abnormality. Individual records were kept on all plants, and, at the end of the experiment, calculations were based on the first 10 typical plants per plot, Nos. 11 and 12 being considered as replacements for Nos. 1 and 2, respectively. Infrequently, losses in excess of 2 plants resulted in fewer samples.

The plots were randomized separately for each parcel, with only three modifications to avoid excessive grouping of some treatments, and arranged linearly, beginning at one corner of each parcel. They followed consecutively, doubling back along parallel rows so that many plots carried over into the adjoining row.

Natural infection and defoliation were prevented by spraying with an organic fungicide, Fermate, at 5- to 7-day intervals during the greater part of the experimental period.

The plants in each plot were defoliated in accordance with the applicable treatment at the beginning of the experiment. Thereafter all the plants were examined every 3 or 4 days, and each was treated when the leaflets had just completed their expansion and were beginning to raise themselves into the mature position (fig. 1, *E*). This stage was selected as a base for making the treatments and dating flush formation, as it is an easily recognized stage of development that lasts but 3 or 4 days. It is also the first stage at which natural defoliation by target spot occurs.

Controlled defoliation was effected through the systematic removal of whole leaflets. Beginning with the lowest leaf in the flush, which typically bears its leaves in a clockwise spiral (fig. 1, *E*), and moving in the same direction, the leaflets were counted off in sets of five, regardless of whole leaves. Each leaflet had a value of 20 percent. Starting with the first leaflet of each set, in treatments 2 to 6, from one to all the leaflets were removed with scissors, taking care to leave the petiolule that abscissed naturally within a few days. If the flush terminated in less than a complete set of five leaflets, the first leaflet of the incomplete set was marked and the next treatment was begun at that point when a new flush was formed. In this manner, approximately equal numbers of large, medium, and small leaflets were removed from among the successive flushes.

By recording only the number of leaves initiated per flush at the time of each reading and treatment, it was possible to compile data on both leaf and flush development.

Height measurements were made in centimeters at about monthly intervals from ground level to the top of the last treated flush. Thus, they represent minimal heights, as many young, elongating terminal flushes were not included. Diameter measurements were made in millimeters every 2 months at a height of 10 cm. from the ground, which approximates the level at which low buddings are made. There was no deep cultivation during the experiment, although weeds were removed periodically by pulling or cutting.

Statistical calculations were based only on the first five treatments, for more than 70 percent of the plants in treatment 6 were dead at the end of 4 months. The results for treatment 6 are shown graphically in most of the figures in order to complete the data and because the persistence of the plants despite complete defoliation may be of interest.

RESULTS

More than 800 plants, of which 680 formed the basis for the present report, were measured throughout the course of the experiment. The results for each parcel were calculated separately. As the results obtained in each were similar and the differences between them mostly statistically insignificant, they have been combined for presentation.

Consideration of the entire experiment, including measurements of the number of leaves initiated per flush, the number of flushes per plant and days between flushes, the progressive increase in height and diameter, and the distribution of the plants by size classes, suggests that the defoliation treatments may be considered in two main groups. Treatments 1, 2, and 3 (0-, 20-, and 40-percent defoliation) permitted satisfactory development of the plants. Treatment 1 permitted the best growth. Treatment 3 consistently reduced growth, although it permitted satisfactory development. Treatment 2 was variable, alining itself with either of the other treatments in the two parcels, but seldom taking an intermediate course.

Treatments 4, 5, and 6 (60-, 80-, and 100-percent defoliation) constituted the second group. All led to unsatisfactory development, with marked depression of growth at 60-percent defoliation, barely more than survival at 80-percent, and death of the plants within a few months when they were completely defoliated.

The number of leaves initiated by successive flushes on plants in the several treatments is shown in figure 8. There were significant

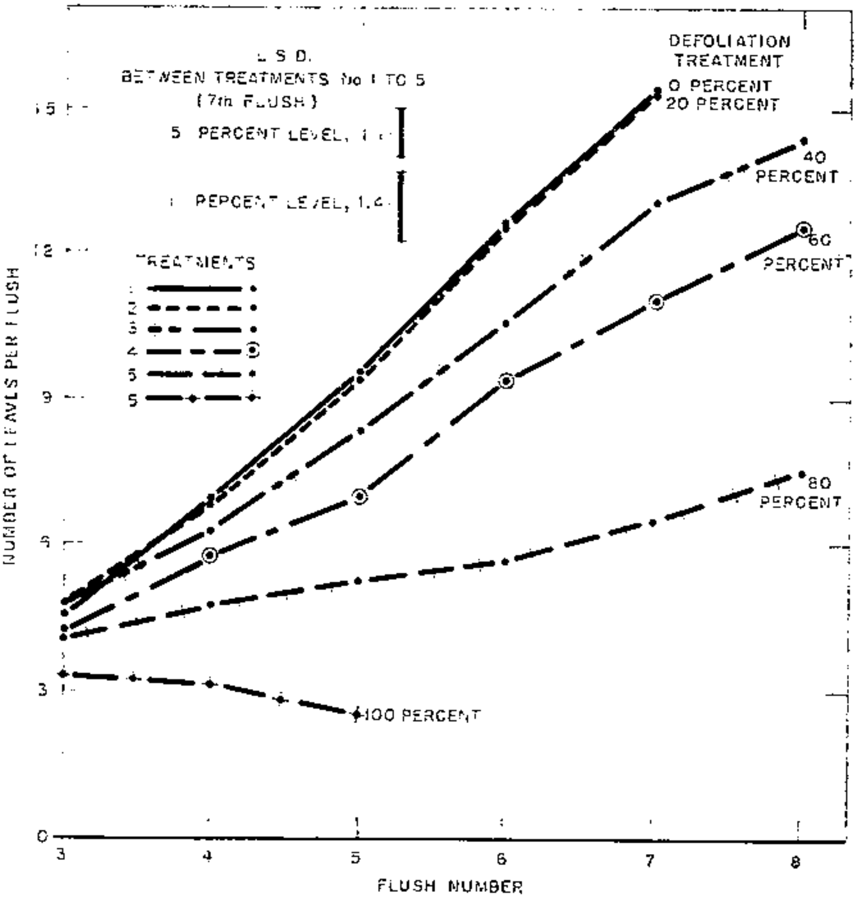


FIGURE 8.—Influence of six defoliation treatments on the production of leaves by successive flushes of hevea seedlings.

differences at the 1-percent level among all the treatments except 1 and 2, based on the number of leaves in the seventh flush. A reduced number of leaves per flush in combination with leaf removal led to a marked restriction of effective leaf area in the more drastic treatments. The reduction in leaf area was further aggravated by the reduced average leaf size on such plants, although no details are available on this point. Defoliation also influenced the frequency with which the plants produced new flushes. The figure shows that many plants in treatments 3, 4, and 5 produced eight flushes each. As might be expected, all plants did not produce equal numbers of flushes even in the same treatment. Therefore, the final point of each curve was that at which at least 50 percent of the plants in a given treatment produced seven or eight flushes, respectively.

More details on the influence of defoliation on the frequency of flushing are shown in figure 9. The first two treatments were almost equal with reference to the number of days between flushes, but

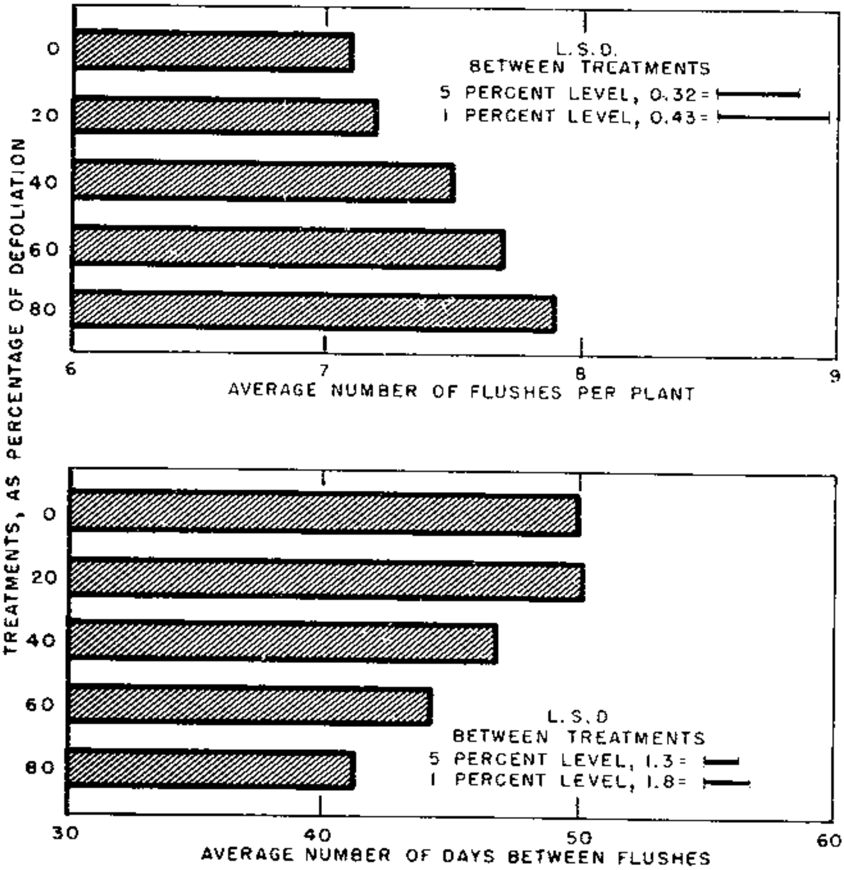


FIGURE 9.—Number of flushes produced per plant in five defoliation treatments and number of days between flushes, by treatments, based on the average of the intervals between the fourth and seventh flushes.

there were significant differences between all other treatments, at both the 5- and 1-percent levels. The decreased number of days between flushes with the more severe treatments is reflected in an increased average number of flushes per plant. There were significant differences between treatments 1 and 2, and 4 and 5, considered as groups, with treatment 3 occupying an intermediate position. Prolongation of the experimental period would have augmented the differences.

The influence of defoliation on the growth in height of seedlings is shown in figure 10. There were highly significant differences among all treatments. Treatment 2 was the only variable treatment, being in one parcel similar to treatment 1 and in the other alined with treatment 3.

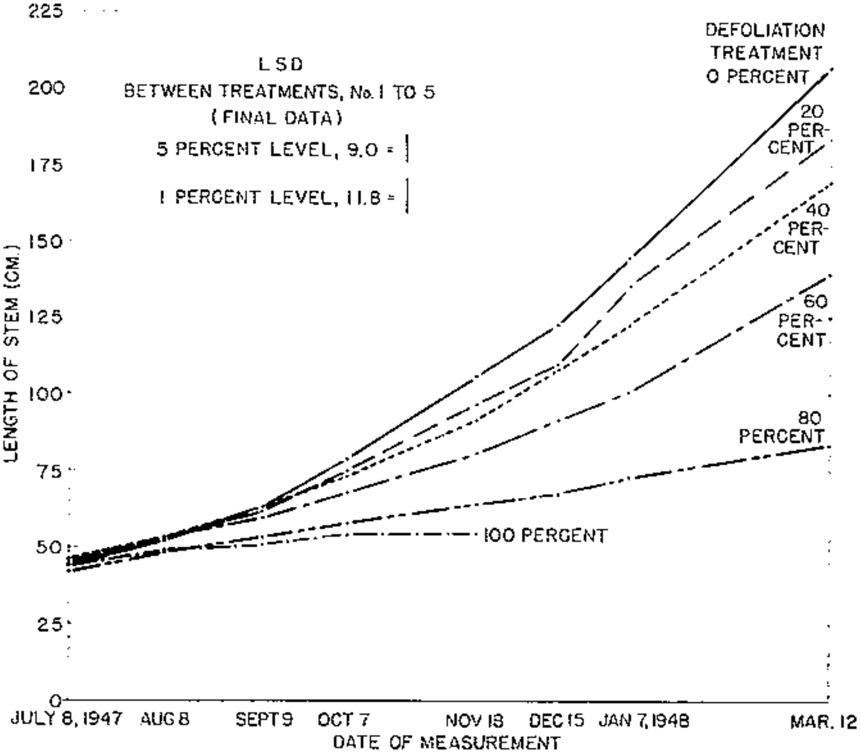


FIGURE 10.—Influence of six defoliation treatments on the growth in height of hevea seedlings.

In order to express more accurately the relative volumes of growth obtained by the various treatments, the rate of increase in diameter of the stems was expressed as cross-sectional area (fig. 11). When size was expressed as diameter, the plants subjected to 80-percent defoliation were about one-third the size of undefoliated plants; when expressed as cross-sectional area, the same plants had less than one-eighth the volume of growth of those in treatment 1.

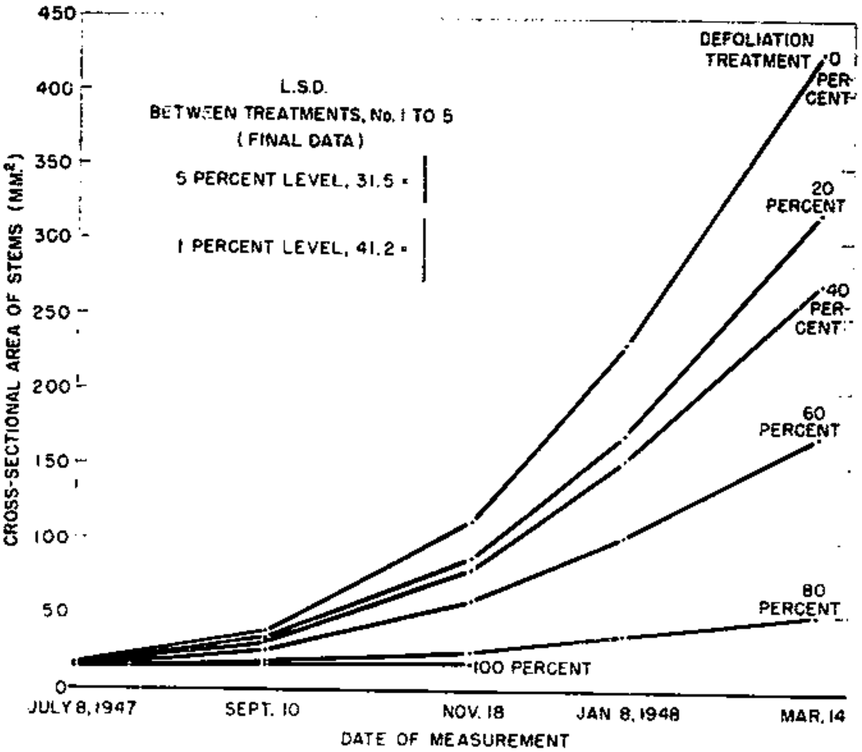


FIGURE 11.—Influence of six defoliation treatments on the growth in diameter of hevea seedlings, expressed as cross-sectional area of stems at budding height.

There were highly significant differences among all treatments. It appears that its influence on diameter is one of the best criteria for judging the effects of defoliation in hevea. Diameter is also one of the most important factors when considering the influence of defoliation on the production of grafting stocks.

The distribution of plants by size classes within the several treatments (fig. 12) shows most forcibly the influence of defoliation, as the achievement of good budding size in minimal time is a prime objective in raising seedling stocks. The treatments fall into two groups if a diameter of 16 mm. is taken as the minimum size for good budding success. This arbitrary minimum was selected on the basis of general practice, recognizing that there may be numerous valid exceptions. Incidentally, diameter measurements after 6 months of treatment (fig. 11) and when the plants were 8 or 9 months old showed that 59 percent of the seedlings were of buddable size in treatment 1, 33 percent in treatment 2, and less than 25 percent in any other treatment.

The terminal data for the experiment are summarized in figure 13 to permit a comparison of the several measurements by treatments. The effects of defoliation were consistent among all the aspects of growth that were measured.

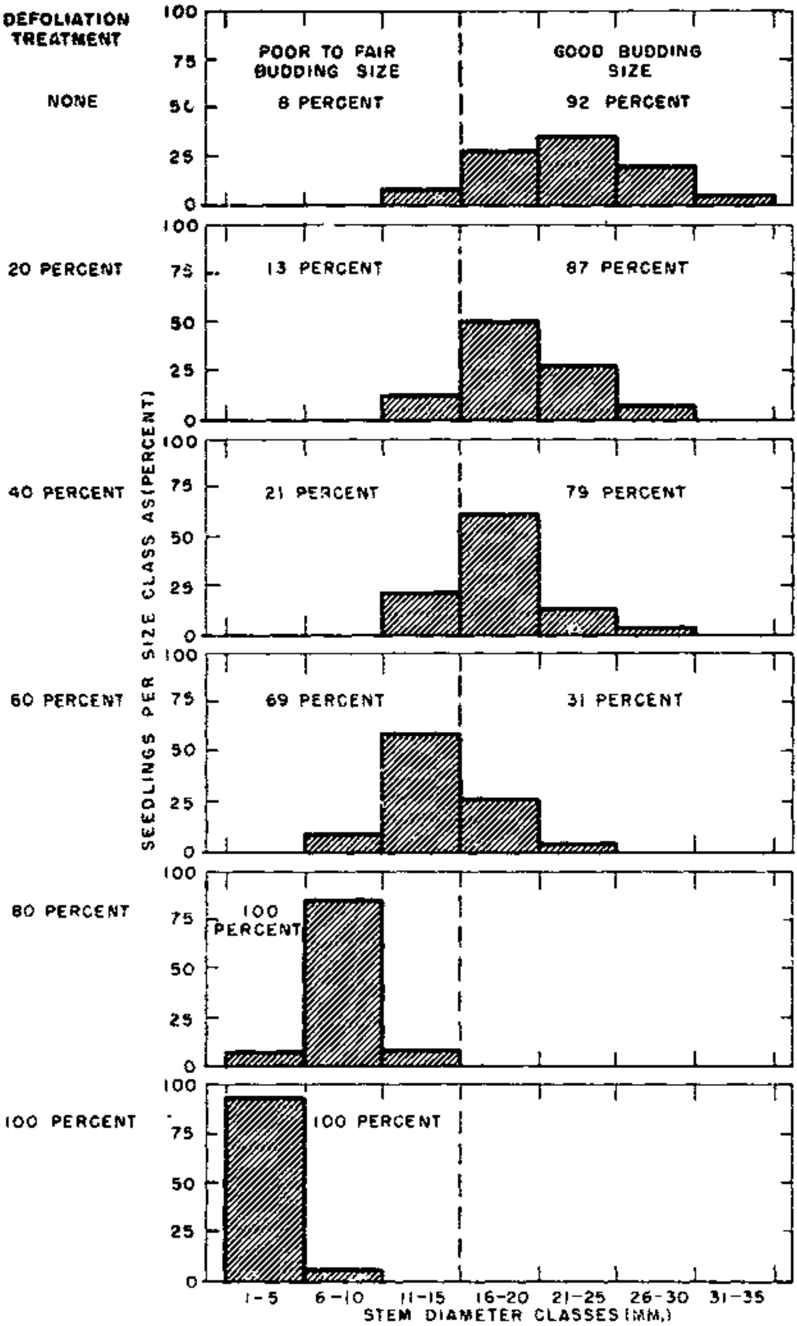
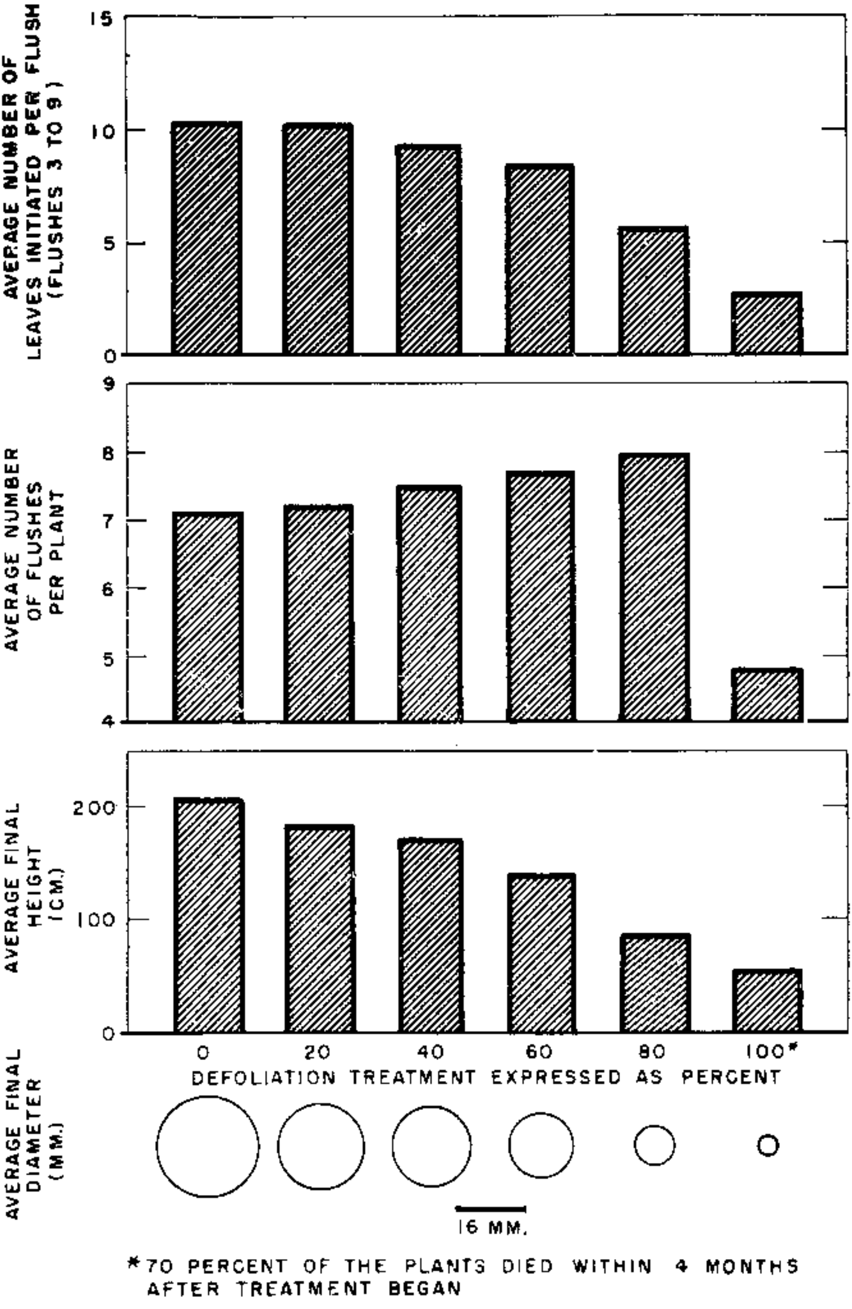


FIGURE 12.—Influence of six defoliation treatments on the distribution of hevea seedlings among size classes based on diameter, at 10 to 11 months of age and after 8 months of continuous treatment.



*70 PERCENT OF THE PLANTS DIED WITHIN 4 MONTHS AFTER TREATMENT BEGAN

FIGURE 13.—Influence of six defoliation treatments on number of leaves initiated per flush, number of flushes per plant, and growth in height and diameter of hevea seedlings at 10 to 11 months of age and after 8 months of continuous treatment.

FUNGICIDAL CONTROL

The development of fungicidal control measures for target spot was the most urgent problem at the time these studies began. Screening tests to determine the spraying, dusting, and phytotoxic properties of various fungicides and adjuvants, singly and in combination, began in June 1946. The better formulas found in those trials were used in comparative fungicidal trials from October 1946 to February 1947 at Tingo Maria. The practicability of fungicidal control has been confirmed by annual nursery-spraying programs.

METHODS AND MATERIALS

The fungicides were used at strengths recommended for other foliage diseases. Several materials were used in various combinations, as no prior controlled trials against this disease had been made on rubbertrees. The sprays were applied weekly with a 50-gallon capacity, high-pressure, portable sprayer on pneumatic tires, an important consideration in high-rainfall areas. The dusts were applied weekly with a knapsack-type duster, modified by substituting a flexible hose for part of the metal discharge tube. All of the dust mixtures were prepared locally.

The experimental plants were derived from 3-year-old seedling nursery trees in beds, cut back to a height of 30 cm. Each stump was allowed to develop one shoot in order to approximate young nursery conditions. These plants were satisfactory, except that growth was more exuberant than in young seedlings, probably because of the larger root system. The plants outgrew their usefulness after 4 months, when they were about 2 meters high, because of the close proximity of the various plots.

Spray plots measured 2 by 10 meters; dust plots, 2 by 5 meters. Each spray treatment was replicated four times and each dust treatment three times, with the plots distributed at random. Although the plots were close together, the effects of drift were negligible, because spraying and dusting were done only in quiet weather. As a further precaution, the dust plots were separated by alternate beds of untreated trees, pruned at a height of 1 meter and allowed to develop into a dense hedge.

Abundant inoculum was provided from beds of tall seedling trees bordering and traversing the experimental blocks and by the untreated plots.

Host- and disease-development records were made on 10 tagged flushes per plot, and the data from the 4 unsprayed and 3 undusted controls were combined and calculated as simple averages. Readings were made every 3 or 4 days on the untreated control plots and about weekly on the treated plots. The data included the total numbers of leaves, infected leaflets, and defoliated leaflets and were cumulative, so that the readings represent totals as of any given date after October 23, 1947. Defoliation due to causes other than target spot was negligible.

RESULTS

The natural course of target spot, including leaf production, infection, and defoliation, is indicated in figure 14, which presents the

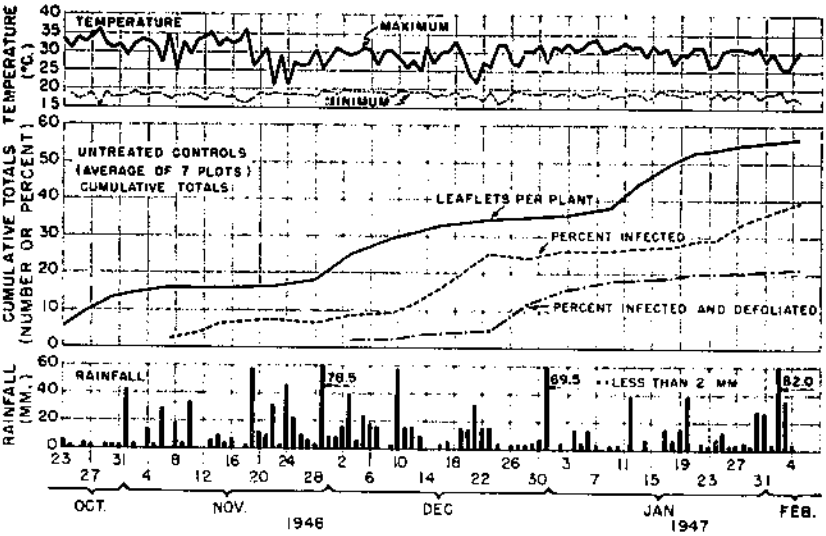


FIGURE 14.—Host and disease development in the untreated control plots of fungicidal experiments for control of target spot of hevea rubbertree.

results of the host- and disease-development studies on the untreated control plots, accompanied by temperature and rainfall records. Infection occurred soon after the first flushes were formed and their foliage began to unfold and expand. The number of infections increased steadily under conditions favoring the disease. Defoliation started a few weeks after the infections first appeared. Whenever substantial new growth was made, as during a flush period,[7] corresponding increases in infection and defoliation followed immediately. Although the data cover a period of only 3½ months, this cycle of events continues during the rainy season, usually from November to May, inclusive. During the dry season, the incidence of disease was sharply reduced so that there were few infections and negligible defoliation.

The weather records show the heavy rainfall and moderate temperatures that prevailed during the disease-control experiments. Frequent long daily periods of high humidity, fog, and light to heavy overcast also contributed to the favorable conditions for disease development.

In the ensuing discussion of disease control, it may be noted that the incidence of infection remained rather high, although defoliation was largely prevented by the better treatments. This apparent discrepancy is dealt with in the Discussion (p. 27).

The results of the spray trials appear in figure 15, which gives the percentages of infection and defoliation in terms of the maxima,

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[7] Individuals in young seedling populations or in groups of plants severely pruned at one time tend to produce their earliest flushes at approximately the same time, which may be termed a flush period. The tendency is gradually lost as each plant establishes its characteristic habit, and this periodicity gives way to a rather uniform condition of mixed growth stages.

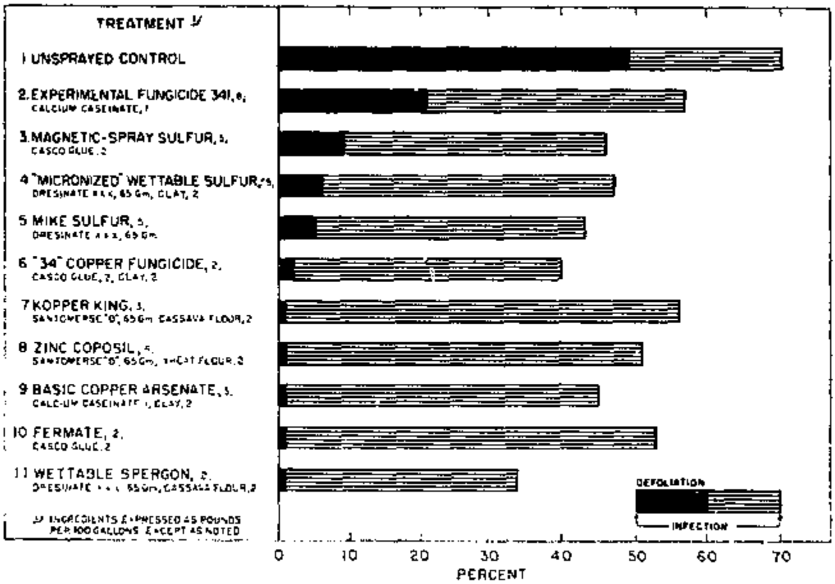

FIGURE 15.—Comparison of 10 spray treatments applied at weekly intervals for control of target spot of hevea rubbertrees.

most of which occurred in January 1947. They were essentially the same as the final data taken in February. Control was good, with 2-percent defoliation or less where insoluble copper fungicides or organic fungicides were used. Wettable sulfurs were a little less effective, permitting from 5- to 9-percent defoliation. Wettable Spergon was the most efficient material; it held defoliation to 1 percent and sharply reduced foliage infection. The occasional slight injury associated with this fungicide was expressed as a yellowish discoloration immediately beneath heavy spray deposits. A characteristic sweetish odor was always present in the plots sprayed with this fungicide, suggesting that some component was volatile. The experimental fungicide 341, 2-heptadecyl glyoxalidine, gave relatively poor control. However, the manufacturer also became aware of some difficulty with the same lot and advised the cooperators.

The results of the dusting trials appear in figure 16, which gives the percentages of infection and defoliation in terms of the maxima, most of which occurred in January 1947. They were essentially the same as the final data taken in February.

The combination of Fermate and Swan sulfur gave good control, with only 1 percent of defoliation. Plants receiving this dust were outstanding throughout the period of the trials for the excellence of their foliage and growth. Although more than 30 percent of the foliage was infected, the lesions were generally delimited while small.

Distinct differences in the dusting properties of the several mixtures were observed, and their relation to control is evident. Swan brand dusting sulfur had the most suitable properties, both alone

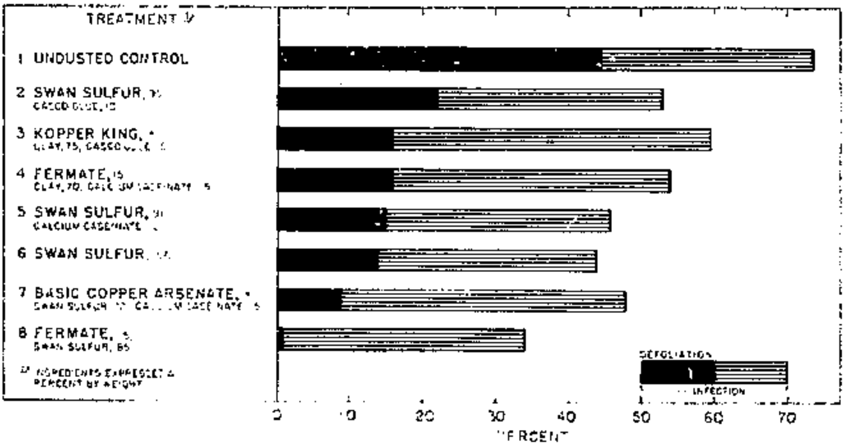

FIGURE 16.—Comparison of seven dust treatments applied at weekly intervals for the control of target spot of hevea.

and with Fermate. Fermate is also a light, readily dispersed powder of extremely fine particle size. Mixtures containing putty clay of local origin had inferior dusting properties and were difficult to apply. Fermate also gave poor control when combined with clay. Thus, glue and clay impaired the dusting properties of mixtures in which they were components. Calcium caseinate had no adverse influence on the dusting properties of the mixtures. Though the preparation of basic copper arsenate, Swan sulfur, and calcium caseinate gave good control, it was too heavy to be satisfactory.

Dusting has not been recommended for general use because adequate dusting equipment has not been available and the best mixture —sulfur and Fermate—has caused some nausea and headaches even with experienced operators.

Since 1947 nursery spraying has been practiced at Tingo Maria annually during the greater part of the rainy season to control target spot. Good control has been maintained with weekly spray applications carefully applied by local operators. Insoluble copper fungicides, chiefly Kopper King, with a spreader-sticker such as calcium caseinate or wheat flour, have been used at the concentrations indicated in figure 15. These have been more readily available and cheaper than the organic preparations. Satisfactory control was obtained also at Plantation Yurimaguas No. 2 in 1947 and 1948 when careful weekly applications of the same fungicides were made.

DISEASE RESISTANCE

Beginning in November 1946, evidence of disease resistance against target spot was sought in a survey of clones recommended for commercial planting, experimental clones and selections, and seedling populations of hevea rubbertrees.

METHODS AND MATERIALS

The disease-resistance trial area was established in 1947 by a modification of Langford's (*10*) leaf-blight-testing plot technique, so that 3 beds of test plants alternated with a single bed of highly susceptible seedlings, the latter to furnish abundant inoculum. This method of testing exposed every plant to heavy inoculum over a minimal period of several months. The clones and selections under study were planted in linear plots of 10 plants each when this number was available.

The clones and selections included in the trial area were selected from those reported to be tolerant to target spot in Peru,[8] recently imported clones whose behavior under Peruvian conditions was unknown, local seedling selections that had maintained at least 50 percent of their foliage in each of three successive flushes during the rainy season, and a few leaf-blight-resistant clones currently recommended for top working. The Eastern clones were excluded because of their known high susceptibility.

In addition to the collections in the trial area, the clone collections and seedling populations at Tingo Maria, Iquitos, Plantation Yurac No. 1, Plantation Yurimaguas No. 2, and Fundo Iberia, in Peru, and plantings at Belem, Belterra, and Porto Velho during a brief assignment in Brazil were observed.

Disease ratings were made on the basis of the percentage of defoliation, in four classes: 0- to 25-, 26- to 50-, 51- to 75-, and 76- to 100-percent defoliation. The results obtained in the experimental defoliation studies indicate that in future studies it might be advisable to change over to five classes, at 20-percent intervals.

RESULTS

A summary of the diverse groups of plant materials tested in the disease-resistance trial area or examined in field and nursery plantings during the course of the study on disease resistance follows:

1. Clones and selections of hevea tested for resistance to target spot in the disease-resistance trial area.[9]
   A. *Hevea brasiliensis:*
      a. Ford Brazilian clones: F 212; FB 51, 3363.
      b. Peruvian clones: Department of Loreto, mostly near Iquitos, P 1, -2, -25, -32, -39, -49, -65, -66, -106, -110, -112, -114, -143, -164, -168; Department of Madre de Dios, mostly near Iberia, P 116, -117, -118, -119, -121, -122, -123, -139, -177, -178, -180, -209, -218, -221, -241, -255, -293, -300, -301, -307; Belem seedlings, grown at Tingo Maria, Peru, P 76, -90.
      c. Provisional seedling selections for target-spot resistance, made in Peru, by origin and number of selections: Madre de Dios, Peru, 27; Iquitos, Peru, 8; Leticia, Colombia, 7; Turrialba, Costa Rica (from Eastern clones), 9.
   B. Intraspecific hybrids of *H. brasiliensis* (Eastern and Brazilian clones):
      a. Ford clones: FX 16 (F 1166 × AV 49); FX 25, -87 (F 315 × AV 49); FX 1012, -1029 (F 351 × PB 186); FX 1042 (F 1425 × PB 186); FX 2187, -2261 (F 1619 × AV 183); FX 2851 (F 216 × AV 49); FX 2855, -2856 (F 570 × AV 49).

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[8] Office report of R. J. Seibert, formerly senior geneticist, Division of Rubber Plant Investigations.

        b. **Instituto Agronômico do Norte clones: IAN 443 (TJ 1 × F 409); IAN 486 (F 351 × PB 186); IAN 506 (F 351 × Pil 84); IAN 713 (PB 86 × F 409); IAN 735, –736, –739 (PB 86 × FA 1707); IAN 833, –891, –898 (PB 86 × FA 1717); IAN 936 (PB 86 × F 351).**

    C. **Interspecific hybrids:**

        a. ***H. brasiliensis*** **crossed with** ***H. benthamiana*** **(Eastern and Brazilian clones): FX 157, –199, –200, –212 (F 4542 × AV 183); FX 334, –360, –379, –393, –490, –516, –561, –575 (F 4542 × AV 363); FX 469, –614, –644, –645, –652, –664 (F 4542 × TJ 1); IAN 500, –505 (TJ 1 × F 4542); IAN 586, –597 (PB 86 × F 4537); IAN 717, –722 (PB 86 × F 4542).**

        b. ***H. guianensis*** **×** ***H. brasiliensis*** **(Eastern and Brazilian clones): FX 2567 (F 5566 × PB 186).**

        c. ***H. brasiliensis*** **×** ***H. guianensis*** **var.** ***lutea*** **(putative natural hybrids from Peru): P 127, –128, –129, –130, –131.**

        d. ***H. brasiliensis*** **crossed with** ***H. spruceana*****, Brazilian clones: F 6398.**

    D. ***H. benthamiana*** **clones, Brazilian: F 4511, –4515, –4527, –4540, –4541, –4542.**

    E. ***H. guianensis*** **clones, Brazilian: F 5004.**

2. **Additional hevea clones, species, and seedling populations examined for evidence of target spot resistance in both Peru and Brazil.**

    A. ***H. brasiliensis:***

        a. **Eastern clones: GA 49, –255, –308, –1264, –1279, –1301, –1518, –2075; GS 16, –181, –576; GV 21, –31, –37, –42; GX 26, –410.**

        b. **Ford Brazilian clones: F 170, –176, –211, –315, –396, –409, –1168, –1425, –1504, –1619, –1620, –1639; FA 1705, –1710, –1717; FB 14, –30, –38, –45, –54, –55, –74, –79, –96, –110, –116, –3112, –3300, –3333, –3363, –3377, –3381.**

        c. **Costa Rican clones: Tu 41–1, –2, –3, –9, –10, –22; Tu 42–5, –23, –40, –44, –49, –71, –86, –94, –136, –177.**

        d. **Peruvian clones: Department of Loreto, mostly near Iquitos, P 108, –113, –145; Department of Madre de Dios, mostly near Iberia, P 138, –173, –181, –184, –186, –187, –188, –189, –192, –193, –194, –195, –196, –197, –198, –199, –202.**

        e. **Colombian clones: (principally** ***H. brasiliensis*****): COL 116, –123, –202, –203, –205, –208, –210, –212, –220, –221, –224, –228, –230, –231, –232; LET 11, –15, –24, –35.**

    B. **Interspecific hybrids, Ford Brazilian clones:**

        a. ***H. benthamiana*** **×** ***H. brasiliensis*****: FX 322, –355, –357, –365, –378, –385, –388, –432, –475, –497, –546, –555, –566, –582, –588, –590 (F 4542 × AV 363); FX 465, –615, –618, –623, –626, –627, –629, –636, –639, –640, –642, –643, –649, –658, –660, –662 (F 4542 × TJ 1).**

        b. ***H. brasiliensis*** **crossed with** ***H. spruceana:*** **F 6395.**

    C. ***H. benthamiana*****, Brazilian clones: F 4507, –4528, –4529, –4537, –4543.**

    D. ***H. guianensis*****, Brazilian clones: F 5345, –5466, –5566.**

    E. ***H. guianensis*** **var.** ***lutea*****, Peruvian clones: P 152, –153, –236.**

    F. **Other species, of Brazilian origin:** ***H. microphylla*** **Ule,** ***H. pauciflora, H. rigidifolia*** **(Benth.) Muell. Arg.**

    G. **Nursery seedling populations: Of diverse origins from Brazil, Colombia, Costa Rica, and Peru.**

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[1] The several series of hevea clones used in this study were: (*a*) Ford clones of Brazilian origin, selected by Companhia Ford Industrial do Brasil (Ford Motor Co.): F, clones from miscellaneous seedling selections; FB, clones from Belém seedlings; FA, clones from Acre jungle trees; FX, selected progeny from hand-pollinated crosses; (*b*) Eastern clones from Sumatra: AV(ROS) = Algemeene Vereeniging van Rubberplanters ter Oostkust van Sumatra; PB = Prang Besar estate; Pil = Pilmoor estate; TJ = Tjirandji estate; (*c*) IAN = Instituto Agronômico do Norte clones of Brazilian origin; (*d*) P = Peruvian clones from jungle trees and nursery seedlings (*a*); (*e*) GA, GS, GV, and GX clones of the Goodyear Rubber Plantations Co.; (*f*) Tu = Turrialba, Costa Rican clones of the U. S. Cooperative Rubber Plant Field Station (Tu 41, selections from Belém seedlings in 1941; Tu 42, selections from Acre seedlings in 1942); (*g*) COL = Columbian clones, mostly from the State of Amazonas; and (*h*) LET = Leticia clones, Amazonas, Colombia.

Among all of these collections, only a few clones and species have shown tolerance or resistance to target spot. *Hevea rigidifolia* appears to be highly resistant. No lesions have been reported or observed on the few collections of that species. It is a noncommercial, slow-growing tree with coriaceous foliage, but it may have some value as a breeding clone.

Certain clones of *H. benthamiana*, such as F 4515, –4527, and –4542, are apparently tolerant or resistant to target spot. The clones mentioned had less than 50-percent defoliation in the disease-resistance trial area, and some individuals practically escaped defoliation, although lesions were present. Clone F 4542 has also shown promise in Brazil as a top-working clone because of its high resistance to leaf blight.

Some selections of *Hevea pauciflora*, though susceptible, appear to be more tolerant of the disease than top-working clones of certain Ford series. A few selections used for top working in the Utinga Plantation at Belém, Brazil, maintained well over 50 percent of their foliage when adjacent plants of *H. brasiliensis* clones were heavily defoliated.

Among the currently recommended top-working clones, FB 54 and FB 3363 seem to be tolerant to target spot in the field, although highly susceptible in the disease-resistance trial area and in budwood gardens. These two clones are generally less severely attacked than the other top-working clones in the field in Peru and, even when severely defoliated during the rainy season, possess the ability to produce successive flushes regularly.

Fortunately, target spot appears to be an important disease only on young plants, for the problem of obtaining resistance to it is complicated by the need of maintaining a high level of resistance in top working clones to the South American leaf blight, caused by *Dothidella ulei* P. Henn., the major disease of hevea in tropical America (*9, 10, 11, 13*). The use of leaf-blight-resistant clones for top working susceptible, high-yielding Eastern clones has become a common practice wherever plantation rubber is grown in the Western Hemisphere.

DISCUSSION

Development of control measures against the target leaf spot of hevea rubbertrees was the most urgent objective of the investigations on this disease, which began in Peru in 1946. A fungicide-testing program was started in June and disease-resistance studies somewhat later. Concurrently, studies on host development and epidemiology were undertaken to provide a better understanding of the applicability of disease-control measures and to gain further information about the disease itself. Relationships among several factors that may influence disease development and control are considered here.

Satisfactory control of target spot was maintained with the better fungicidal treatments, both experimentally and in field practice, but a striking feature of the data for both dusting and spraying was the relative incidence of infection and defoliation. Even though defoliation was reduced from about 45 percent to 2 percent or less by the better fungicidal treatments, the incidence of infection was not reduced proportionately. Usually 35 percent or more of the leaflets were infected, although the number of lesions per leaf was sharply reduced and the lesions limited to approximately 1 cm. in diameter. Untreated plants had about 70 percent of the leaflets infected. In this connection, the rapid development of the flush is of interest and importance when considered from the standpoint of the fungicidal control of target leaf spot and other foliage diseases of hevea.

The persistently high incidence of infection appears to be directly associated with the growth habit of young rubber plants, which grow almost continuously during their first 2 or 3 years. Within any sizable population, there are always some individuals in each stage of development. Unfolding and expansion of the leaves occur within 8 to 12 days and 15 to 21 days, respectively. The interval between flushes is only about 6 to 7 weeks under good growing conditions. Growth is continuous and rapid during the period of leaf elongation, with the leaves elongating from 2 to 3 cm. per day during the most active period of growth. This is an average rate of about 1 mm. per hour, both during the day and night.

When fungicides are applied at weekly intervals nearly all of the leaves on a given flush may be unfolded during one interval, and during two or three consecutive intervals the leaves complete their expansion. Moreover, the expanding leaflets are pendent and glossy, neither condition encouraging the retention of fungicides. Fungicidal deposits soon become widely dispersed and can afford only partial protection. Although infections may occur on the foliage as a result of rapid growth and the attendant dispersal of fungicidal residues, fungicidal action reduces the number and size of the lesions. They are restricted to about 1 cm. in diameter by successive applications, especially to fully expanded leaves, that prevent the growth of the superficial mycelium, which is apparently the only means of spread from the primary lesions. Some of the infected tissue eventually dries and shatters, giving a shot-hole appearance to the leaves. Experimental defoliation studies indicate that the plant may tolerate the removal of 20 to 40 percent of its foliage and still make serviceable growth. Realizing that the loss of leaf area by lesions and by leaf removal may not have strictly comparable effects on over-all leaf efficiency, observations indicate, nevertheless, that the better fungicidal treatments prevent the loss of sufficient leaf surface to affect growth adversely. Therefore, weekly applications of fungicides have been considered sufficiently frequent to satisfy the requirements for controlling this disease.

Drastic experimental defoliation treatments had the most dramatic effect on growth, a result predictable from observations of the disease. However, the more important results were those obtained from treatments involving more moderate defoliation, where simple observation is less reliable.

The ability of young hevea plants to tolerate the loss of up to 40 percent of their foliage and still grow well is important from the standpoint of plant production. If moderate infection and defoliation are relatively unimportant, in areas where this is the only important foliage disease, fungicides might be applied for a minimum period during the rainy season and at weekly intervals. This condition existed at Tingo Maria until the early part of 1949; thereafter, the South American leaf blight became serious. When leaf blight is present and serious, more frequent applications of fungicides (*4, 9, 11*) may be required. Fortunately, the same fungicides control both diseases.

Target spot is rarely fatal in the absence of complicating factors, for a few leaves on each plant usually escape defoliation or even infection, permitting survival until dry weather suppresses the disease and sound foliage may be produced again. Where target spot is common, the plants that suffer most are those that begin to produce or renew their foliage during and after the onset of the disease in the rainy season—seedlings, buddings, or recently pruned plants in clone-multiplication gardens—as these have no reserve foliage. Root and stem reserves of nutrients in the larger established plants seem to counteract this lack to some degree. Small seedlings or recent transplants may be permanently damaged or indirectly killed by repeated severe defoliations that exhaust their reserves or prevent their establishment in competition with cover crops and second growth where field maintenance is substandard.

Fungicidal control offers an effective means of avoiding these conditions, especially in nurseries, but field control remains difficult. Recent proposals that plants intended for field use be held in the nursery until all buddings have been completed to give a 3-component tree[9] (*1, 4, 11*) should assist disease control, as fungicide applications would be feasible until transplanting began. Properly grown 3-component trees used as transplants should establish a good crown of foliage more quickly than low-budded stumps that undergo top working in the field.

Some insight into the ability of hevea to survive in dense forests is afforded by the persistence of rubber plants during several months when completely defoliated and by their slow but steady progress when 80 percent defoliated. Even fewer leaves may permit survival. Plants that survive their more serious competitors, mechanical injury, and innumerable pests are enabled to take advantage of opportunities for growth and gradually assume their place in the middle and upper stories of the forest.

The survey of clones, selections, and seedling populations of hevea for evidence of disease resistance has shown that genetic disease resistance is uncommon, although some degree of tolerance does exist. *Hevea brasiliensis*, the principal commercial species, probably has little or no genetic disease resistance. Nevertheless, two of the currently recommended top-working clones have been tolerant to target spot in field plantings, although they are highly susceptible in denser nursery plantings. Partial resistance might be sought in *H. benthamiana*, and perhaps in *H. pauciflora*, as some

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[9] Three-component trees consist of a seedling rootstock, a trunk of some high-yielding clone, and a leaf-blight-resistant top. Development of methods for producing 3-component trees in the nursery and establishing them successfully in field plantings has been achieved principally through the efforts of E. P. Imle, principal agriculturist in charge, and other personnel of the U. S. Department of Agriculture Cooperative Rubber Plant Field Station, Turrialba, Costa Rica.

selections of them have been markedly tolerant to target spot, even under severe disease conditions. The noncommercial species *H. rigidifolia* appears to be highly resistant or even immune.

Fortunately, it now appears that target spot resistance is not of major importance in the over-all rubber disease-control program. Many years' observation by various investigators[10] (*4, 12*) has led to the belief that target spot is primarily a disease of young rubber plants, in both nurseries and field plantings. Field-planted trees begin to undergo annual leaf change at about 3 years of age, and leaf change occurs during the dry season in Brazil and Peru when the disease is at its lowest ebb. This allows the new foliage that follows leaf change to mature quickly before appreciable infection can occur. Although some vigorous branches continue to flush throughout the year, they represent only a small percentage of the foliage and become progressively fewer. By the third or fourth year after the onset of leaf change, the disease usually becomes negligible through lack of susceptible foliage during the rainy season.

Additional information on the host-parasite relationships of this disease (*3*) has been obtained in studies on basidiospore germination and infection. Germination may occur within 2 hours and infection within 3 hours under favorable conditions, although longer exposure to such conditions naturally leads to heavier infection. The incubation period is rather short and the primary lesions commonly appear before the leaves have expanded fully and assumed their mature position. Thus, with sporulation beginning shortly after sundown and with rapid germination and infection by the basidiospores, it is little wonder that the disease spreads rapidly under favorable conditions and persists during prolonged dry periods in small amounts.

The rather short period during which the leaves are susceptible is interesting, for only leaves less than 1 week old are usually infected. This is before the most active period of growth, so that the leaves make their greatest expansion for some 2 weeks after passing the susceptible stage.

SUMMARY

Studies on the epidemiology and control of the target leaf spot of hevea and investigations on host development have been made, mostly under conditions prevailing at Tingo Maria, Peru.

Leaf expansion occurs simultaneously in both breadth and length. The leaflets of a given leaf are of nearly equal size, although the central leaflet is consistently the longest. Measurements based on the central leaflet serve as an index to the rate of expansion for the entire leaf. The leaves of the flush are unfolded within 8 to 12 days, and the individual leaves expand within 15 to 21 days. The rates of unfolding and elongation are constant, regardless of the prevailing season, although quantitative differences in leaf size occur. The average daily increment of individual leaves, expressed as increase in length, is markedly different, depending upon their position in

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[10] Letter dated April 10, 1948, from M. H. Langford to J. R. Carpenter summarizes several years' observations in Brazil.

the flush, but the total time required for elongation is almost equal for all leaves in the same flush. During the most active period of growth, the larger leaves may elongate from 2 to 3 cm. per day, or about 1 mm. per hour. Elongation, and therefore expansion, is a continuous process during both day and night. The distribution of leaves in the flush by size classes indicates that the first, or lower, leaf is somewhat smaller than the leaves immediately above it, but, beginning with about the sixth leaf, there is a continuous decrease in leaf size up to the terminal one.

The growth characteristics, plus the pendent habit of expanding leaves and their glossy surfaces, influence fungicidal control of foliage diseases of rubbertrees. It is difficult to get satisfactory coverage of the young leaves, and the fungicidal residues are dispersed rapidly, even under a system of frequent applications. Coverage is less difficult with mature foliage.

Target spot weakens the plant principally, if not solely, by reducing the effective leaf area through infection and defoliation. There is no evidence of toxic action and no other parts are attacked. Experimental defoliation of seedlings extended over a period of 8 months, and height, diameter, number of leaves initiated per flush, and number of flushes per plant were measured periodically. Optimum development was obtained when no foliage was removed. When 20 and 40 percent of the foliage was removed, the plants still made satisfactory development. In plots that had up to 40-percent defoliation, suitable numbers of buddable seedlings were obtained within 10 to 11 months. Increasingly severe treatments, in which 60 to 80 percent of the foliage was removed, strongly depressed growth and resulted in a small number of buddable seedlings. Complete defoliation finally resulted in death of the plants, although they managed to survive several months. As the severity of defoliation was increased, the plants tended to flush more frequently.

The tolerance of hevea rubbertrees to slight or moderate defoliation confines fungicidal control of target spot, in regions where it is the only important foliage disease, to the few months when the disease is especially severe. When South American leaf blight is serious, the control program must be adapted to the more exacting requirements for control of that disease. The same fungicides control both diseases. The limits of tolerance to defoliation may serve as a guide in selecting disease-resistant individuals.

Freshly discharged basidiospores may germinate within 2 hours in either light or darkness. Infection of susceptible young leaves may occur within 3 hours under favorable conditions. Longer exposures—for 6, 12, 18, and 23 hours—substantially increased the number of lesions and leaflets attacked. The incubation period between infection and the appearance of symptoms was 6 to 10 days, depending in large part on the condition of the leaf. Most leaves are susceptible for less than 1 week following their unfolding from the growing point, although the most accelerated period of leaf expansion is subsequent to that time and the whole period involved is about 3 weeks.

Target spot was controlled adequately by weekly applications of fungicides, either as sprays or dusts, during the rainy season. The fungicides included insoluble copper preparations, organic compounds, and both wettable and dusting sulfurs. Wettable Spergon gave the best control among the spray preparations, although it occasionally caused slight injury to the leaves. Under local conditions, insoluble copper fungicides have been used for nursery spraying because of their availability and satisfactory performance. A combination of dusting sulfur and Fermate was the most satisfactory dust. Because of the lack of suitable application equipment, however, dusting has not been recommended. Although defoliation was reduced to less than 2 percent by the better fungicidal treatments, the incidence of infection was usually more than 35 percent, owing to the growth habit of young rubber plants. On untreated control plants, the incidence of defoliation was about 45 percent and that of infection about 70 percent.

A survey of large numbers of clones, selections, and seedling populations of hevea has indicated that genetic disease resistance is uncommon, although some degree of tolerance does exist. Clones of *Hevea brasiliensis* are mostly highly susceptible, but two top-working clones appear to be tolerant in field plantings. Genetic resistance might be sought in *H. benthamiana* and *H. pauciflora*, which have yielded some markedly tolerant selections, and in *H. rigidifolia*, a noncommercial species that appears to be highly resistant or immune. *H. microphylla*, another noncommercial species, is probably highly susceptible. Target spot seems to be primarily a disease of young plants. The rubbertree tends to outgrow and escape the disease by the third or fourth year after it ceases to grow continuously and begins to undergo annual leaf change and refoliation, which occurs during the dry season.

The known geographic distribution of target spot has been extended to include Porto Velho, Brazil, and Leticia, Colombia.

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