Stimulation of Bark Renewal of Hevea and its Effect on Yield of Latex

P. DE JONGE

Comparative effects, on bark renewal after tapping Heavea brasiliensis, of treatment with petroleum greases and palm oil, with and without 2,4-dichlorophenoxyacetic acid, were observed experimentally. Increases in latex yield were also observed and therefore studied intensively. Application of 2,4-D formulations above the tapping cut was compared with the standard practice of applying stimulant to scraped bark below the cut. Results of early experiments.

PREVIOUS WORK (BEELY & BAPTIST 1939) has shown that application of controlled quantities of palm oil to the freshly tapped hard bark of old rubber trees improved the subsequent renewal of the bark to a very significant degree. It was suggested that the more rapid and succulent development of the renewing bark following treatment of the tapped panel was due to some extent to the oily layer preventing excessive evaporation of water from the delicate inner cortical tissues exposed by the tapping process. The effect of palm oil was claimed to be due also to the presence of physiologically effective quantities of growth hormones which occur in most vegetable oils.

This pre-war work led to the setting up of an experiment in which were compared the effect on bark renewal of palm oil and several proprietary formulations when they were applied at monthly intervals to the thin film of bark left after tapping during the previous month. For this experiment buddings were used of clone AVROS 50, planted in November 1930 and tapped alternate daily on a half spiral cut.

Three different concentrations of 2,4-D were added to one of the proprietary formulations to test whether the growth stimulating effect of the substance could be transferred to the true cambium and produce an improved latex producing system in the bark. A strip of bark between ¾ to 1 inch wide was painted monthly using a flat paint brush half an inch in width. Care was taken that no overlapping of applications occurred as this has been shown to result in damage to the bark in the case of palm oil.

As the application of a yield stimulating mixture above the tapping cut was found to depress the yield (CHAPMAN 1951), and as no yield recording has been made in the previously mentioned experiment (BEELY & BAPTIST 1939) accurate yield records were taken throughout the three years duration of the experiment under review.

DESCRIPTION OF EXPERIMENT

Treatments

The following treatments were included in this experiment for monthly application above the tapping cut:

1 Control, no treatment to be applied
2 Standard Vacuum product 2295 C
3 Shell product Ensis 352
4 Shell product Otina C
5 Palm oil

6 Palm oil plus 0.02% 2,4-D
7 Standard Vacuum product 2295 C plus 0.02% 2,4-D
8 Palm oil plus 0.1% 2,4-D
9 Standard Vacuum 2295 C plus 0.1% 2,4-D
10 Palm oil plus 1% 2,4-D
11 Standard Vacuum product 2295 C plus 1% 2,4-D
12 Stimulex

Design of Experiment

The experiment was assigned to the boundary rows of a density of planting experiment in which six different planting systems were compared, namely:

A 30 × 30 feet square = 48 trees per acre
B 20 × 20 feet square = 109 trees per acre
C 14 × 14 feet square = 222 trees per acre
D 12 × 12 feet square = 302 trees per acre
E 10 × 10 feet square = 435 trees per acre
F 20 feet triangular = 125 trees per acre

The plots of this density of planting experiment are arranged in a latin square design and the boundary rows of half of this area have been used for the experiment on stimulation of bark renewal, as in *Figure 1*. The figures in parentheses indicate the plot numbers of the density of planting experiment; the capital letters indicate the planting systems, as above; and the thick lines indicate the boundary rows used for the stimulation of bark renewal experiment. There are 18 rectangular shaped plots in the thick lined half of the density of planting experiment over which six different planting systems have been randomised. The boundary rows of each of these plots have been divided into four practically equal portions which form the plots of the stimulation of bark renewal experiment as shown in *Figure 2*.

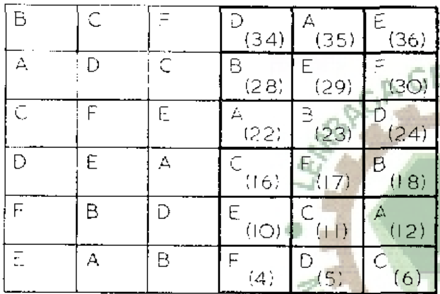

Figure 1. Layout of density of planting experiment.

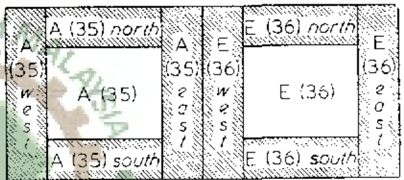

Figure 2. Detail of two plots of Figure 1, showing the plots of the stimulation of bark renewal experiment, shaded.

In this way 72 plots were obtained which allowed six replications of the 12 treatments. As there are six different densities of planting, each replication of a given treatment had to be allotted to a plot of different planting density. The design of this experiment allows a reliable comparison between bark treatments but there are no replications for the study of interaction between bark treatments and planting system. Furthermore the boundary rows do not truly represent the density of planting of the plots to which they belong because of interactions between the densities of the adjacent plots of the different planting systems. The number of experimental trees per plot is given in Table 1.

RECORDING

Bark Renewal

Bark measurements were taken at yearly intervals according to the following schedule (*Figure 3*). At the commencement of the experiment in December 1952 (T_0) one measurement was taken at the place where the tapping cut was estimated to have been in December 1951 (a). A second measurement was taken ½ inch above the centre of the actual tapping cut (b), thus indicating the thickness of bark left after tapping. Both positions a and b were clearly marked on the trees. After December 1952 (T_0) the treatments were applied at monthly intervals to the strip of bark left after tapping during the previous month, except for the control trees which received no treatment.

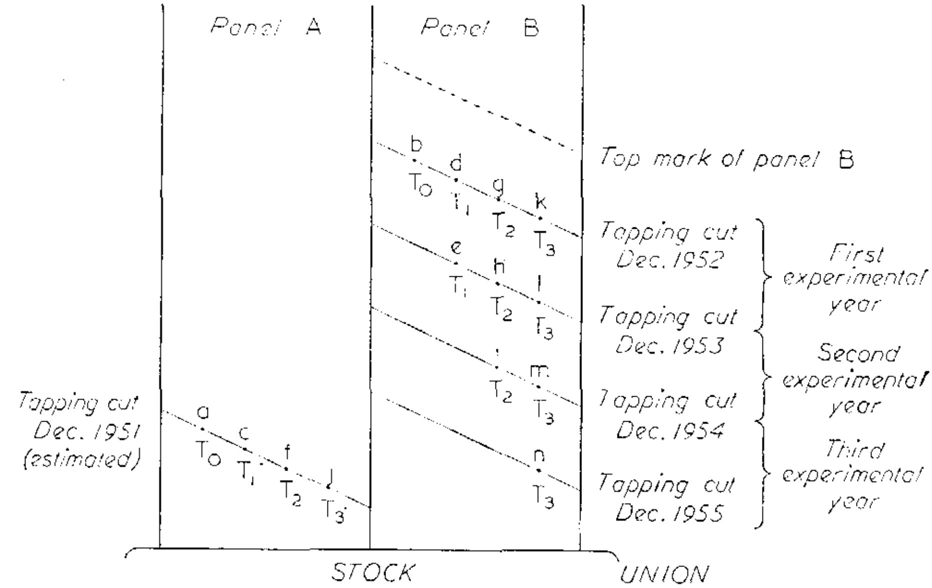

Figure 3. Diagram of a tree giving positions of yearly bark measurements.

The second set of bark measurements was taken in December 1953 (T_1) at one year after commencement of the experiment. Two of the measurements were taken as close as possible to positions a and b, but care was taken to keep clear of the wound reaction due to the earlier measurements. These measurements are labelled respectively c and d. A third measurement was taken at ½ inch above the position of the tapping cut at time T_1 (e) indicating the thickness of bark left after tapping in December 1953.

Application of treatments was continued throughout the second experimental year and a third set of bark measurements was taken in December 1954 (T_2), at positions f (close to c); g (close to d); h (close to e) and i (2 inches above the position of the tapping cut at the time (T_2). Measurement i therefore gives the thickness of bark of approximately two months renewal.

A fourth set of bark measurements was taken at the end of the third experimental year up to which time application of treatments had been continued without interruption. The time of measurements was December 1954 (T_3) and measurements were taken at positions j (close to f); k (close to g); l (close to h); m (close to i) and n (½ inch above the tapping cut at time T_3).

The anatomy of the renewal bark of six trees of each treatment was also studied under the microscope.

Yield

The yield was recorded by coagulation of the latex in the cup once a week. The cup lumps of each plot were then collected, dried for one month in an unheated drying shed and weighed. Recording was done for two months before the bark treatments were applied (pre-treatment recording) and was continued throughout the duration of the experiment. No corrections were made for the water content of the cup lumps after drying.

TABLE 1. NUMBER OF TREES PER REPLICATION OF TREATMENTS

	Treatment	Planting system A	B	C	D	E	F	Total
1	Control	6	7	28	35	22	8	109
2	SVP 2295C	6	9	23	33	37	8	116
3	Ensis 352	6	7	25	32	31	10	111
4	Otina C	5	7	22	26	32	6	98
5	Palm oil	6	10	25	23	36	9	106
6	PO + 0.02% 2,4-D	7	8	26	29	30	8	108
7	2295C + 0.02% 2,4-D	7	11	29	28	34	10	119
8	PO + 0.1% 2,4-D	6	8	27	29	30	5	105
9	2295C + 0.1% 2,4-D	7	8	27	31	32	10	115
10	PO + 1% 2,4-D	6	8	20	30	31	9	104
11	2295C + 1% 2,4-D	6	11	22	26	39	9	113
12	Stimulex	6	11	25	30	40	8	120

TABLE 2. BARK THICKNESS MEASUREMENTS AT ESTIMATED CUT LEVEL DECEMBER 1951

Millimetres

	Treatment	a (T_0) Thick	Effect	c (T_1) Thick	Effect	f (T_2) Thick	Effect	j (T_3) Thick	Effect
1	Control	5.92	0	6.23	0	6.72	0	6.38	0
2	SVP 2295C	5.80	–0.12	6.15	–0.08	6.60	–0.12	6.28	–0.10
3	Ensis 352	6.13	+0.21	6.27	+0.04	7.02	+0.30	6.55	+0.17
4	Otina C	6.97	+0.05	6.07	–0.16	6.60	–0.12	6.53	+0.15
5	Palm oil	6.15	+0.23	6.37	+0.14	6.90	+0.18	6.38	0
6	PO + 0.02% 2,4-D	6.08	+0.16	6.13	–0.10	6.47	–0.25	6.15	–0.23
7	2295C + 0.02% 2,4-D	5.83	+0.09	6.40	+0.17	6.80	+0.08	6.37	–0.01
8	PO + 0.1% 2,4-D	5.98	+0.06	6.20	–0.03	6.77	+0.05	6.22	–0.16
9	2295C + 0.1% 2,4-D	6.02	+0.10	6.18	–0.05	6.80	+0.08	6.38	0
10	PO + 1% 2,4-D	5.87	–0.05	5.90	–0.33	6.72	0	6.13	–0.25
11	2295C + 1% 2,4-D	6.02	+0.10	6.17	–0.06	7.02	+0.30	6.38	0
12	Stimulex	6.13	+0.21	6.18	–0.05	7.02	+0.30	6.33	–0.05

Girth

Girth measurements were taken at a height of 60 inches above the union of all trees included in the experiment. Measurements were taken in December 1952 and 1955.

RESULTS

Bark Renewal

The time and place of the various measurements are indicated in *Figure* 3. Measurements were taken with a Schlieper bark measuring gauge, which consists of a brass tube through which passes a steel plunger with a sharp bladed end. The blade, held horizontally, is pushed into the bark until resistance from the wood is met, when the depth of penetration can be read off to the nearest half millimetre.

Errors may be introduced if different field assistants take the measurements as much depends on the force with which the blade is pushed into the bark. In this experiment each year's series of measurement was taken by one field assistant, but different field assistants were employed in successive years. It was therefore decided to use the differences between measurements taken in any one year for comparing the effects of the bark treatments. The effect of treatments is obtained by deducting the thickness of the bark of the control trees from the thickness of the bark of the treated trees at each position of measurement. This difference is called 'effect' and can be positive or negative.

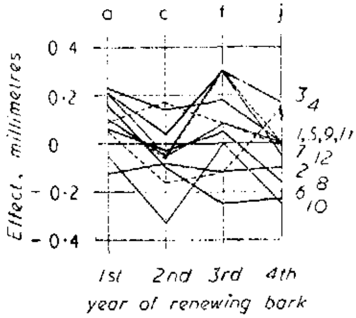

Figure 4. Treatment effects at cut level estimated December 1951. The treatments, as numbered, appear on page 53.

The mean figures of the actual measurements together with the effect figures are given in Tables 2 to 5. In these the measurements taken at the same level have been grouped together to allow for a comparison of effects between successive years. This comparison is brought out more clearly by plotting the effect figures in graphs (*Figures 4* to 7).

Measurements a, c, f, j — See Table 2 and *Figure* 4. Measurements were taken at the time of commencement of the experiment in December 1952 (T_0) at the place where the tapping cut was estimated to have been a year before, in December 1951. This place was determined by counting back twelve of the black dots such as are put on the trees on the first of each month on most estates with the object of keeping a check on bark consumption. The figures turned out to be rather high, suggesting that tapping had been shallow at the level of the cuts which at that time were situated low down on the panel on the opposite side. This should not interfere however, as measurements a, c, f and j, which were all taken at the same level, serve only to show whether the effect of bark treatments can be traced on untreated bark well away from the treated bark.

Any effect due to treatment should show up when bark thickness is plotted against time of measurement (years after first application of treatments). As, however, the actual measurements are not comparable the 'effect' figures are plotted along the ordinate. The effect of the control gives a horizontal zero line. Any treatment effect should then show up by a clear deviation from the control. Examination of the graph for measurements a, c, f and j (*Figure 4*) shows no regularity in any of the treatment lines, which are so closely grouped together that they cannot be clearly distinguished. They are all grouped closely along the control (0) line and therefore do not show any effect due to treatment of the bark at the opposite side of the trees.

Measurements b, d, g, k — Measurement b was taken ½ inch above the tapping cut at the time of commencement of the experiment (T_0) in December 1952 and measurements d, g and k were taken at the same level in December 1953 (T_1) December 1954 (T_2) and December 1955 (T_3). The mean actual bark thickness figures and the treatment effects are shown in Table 3 and the treatment effects are plotted in *Figure 5*. A first glance at this graph shows immediately that, whereas the treatment lines of *Figure 4* were scattered around the control line, all treatment lines are well above the horizontal control. The effects for treatments *10*, *11* and *12* are outstanding. These treatments all contain a comparable concentration of 2,4-D (page 54), and have introduced a highly significant increase in bark thickness. All other treatments fall into one large group and show some increase in bark thickness. The trend of the lines suggests

TABLE 3. BARK THICKNESS MEASUREMENTS AT DECEMBER 1952 CUT LEVEL

Millimetres

Treatment	b (T_0)		d (T_1)		g (T_2)		k (T_3)	
	Thick	Effect	Thick	Effect	Thick	Effect	Thick	Effect
1 Control	3.45	0	4.63	0	4.78	0	4.52	0
2 SVP 2295C	3.47	+0.02	4.90	+0.27	5.13	+0.35	4.87	+0.35
3 Ensis 352	3.40	–0.05	5.02	+0.39	5.48	+0.70	4.95	+0.43
4 Otina C	3.57	+0.12	5.28	+0.65	5.30	+0.52	5.02	+0.50
5 Palm oil	3.43	–0.02	5.00	+0.37	5.15	+0.37	4.78	+0.26
6 PO + 0.02% 2,4-D	3.32	–0.13	4.82	+0.19	5.18	+0.40	4.68	+0.16
7 2295C + 0.02% 2,4-D	3.33	–0.12	5.17	+0.54	5.50	+0.72	5.25	+0.73
8 PO + 0.1% 2,4-D	3.60	+0.15	5.27	+0.64	5.60	+0.82	5.07	+0.55
9 2295C + 0.1% 2,4-D	3.37	–0.08	5.02	+0.39	5.42	+0.64	5.08	+0.56
10 PO + 1% 2,4-D	3.32	–0.13	6.17	+1.54	6.57	+1.79	6.07	+1.55
11 2295C + 1% 2,4-D	3.57	+0.12	7.22	+2.59	7.40	+2.62	6.60	+2.08
12 Stimulex	3.33	–0.12	6.58	+1.95	6.98	+2.20	6.52	+2.00

TABLE 4. BARK THICKNESS MEASUREMENTS AT DECEMBER 1953 CUT LEVEL

Millimetres

Treatment	e (T_1)		h (T_2)		l (T_3)	
	Thick	Effect	Thick	Effect	Thick	Effect
1 Control	3.42	0	4.52	0	4.20	0
2 SVP 2295C	3.35	–0.07	4.75	+0.23	4.42	+0.22
3 Ensis 352	3.42	0	5.07	+0.55	4.60	+0.40
4 Otina C	3.48	+0.06	4.82	+0.30	4.50	+0.30
5 Palm oil	3.67	+0.25	4.87	+0.35	4.60	+0.40
6 PO + 0.02% 2,4-D	3.65	+0.23	4.82	+0.30	4.50	+0.30
7 2295C + 0.02% 2,4-D	3.53	+0.11	4.95	+0.43	4.78	+0.58
8 PO + 0.1% 2,4-D	3.60	+0.18	4.85	+0.33	4.78	+0.58
9 2295C + 0.1% 2,4-D	3.38	–0.04	4.85	+0.33	4.82	+0.62
10 PO + 1% 2,4-D	3.63	+0.21	6.35	+1.83	6.15	+1.95
11 2295C + 1% 2,4-D	3.73	+0.31	6.87	+2.35	6.35	+2.15
12 Stimulex	3.77	+0.35	6.32	+1.80	6.25	+2.05

some additional effect from addition of 0.1% 2,4-D to palm oil or to Standard Vacuum product 2295 C.

It is doubtful, however, if the differences between these treatments would reach the level of significance as this trend is not invariably observed in all replications. The beneficial effect of an oil or grease treatment on the renewing bark is established beyond doubt and is most probably due to prevention of drying out of the delicate inner phloem tissue remaining after tapping. There is no suggestion that palm oil is better than the inert petroleum greases, which does not support the view that the physiological concentration of natural hormones in palm oil would account for the thicker renewed bark (BEELY & BAPTIST 1939).

None of the other treatments can compare with the outstanding effect of any treatment containing a 1% concentration of 2,4-D.

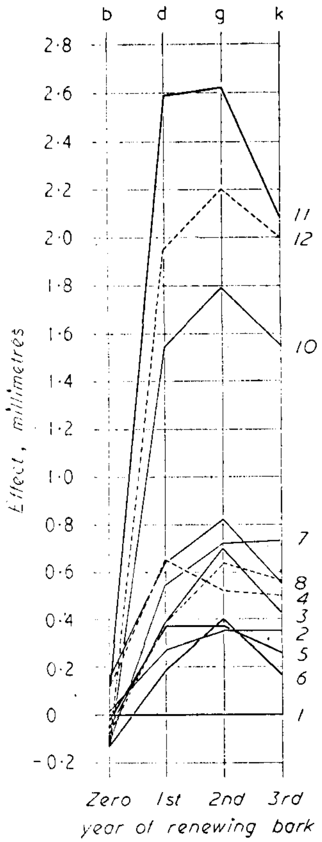

Figure 5. Treatment effects at December 1952 cut level.

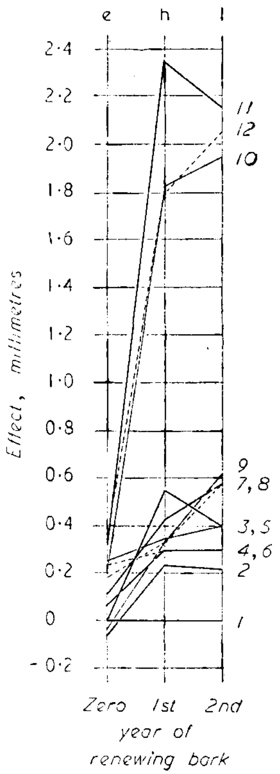

Figure 6. Treatment effects at December 1953 cut level. *See page 53.*

A further feature which can be clearly seen in the graph is the flattening out of the lines in the second year and the downward trend in third year. This observation is interesting as it suggests that almost all of the beneficial effect of bark treatment occurs in the first year of renewal and that in subsequent years the renewal of the control trees improves gradually relative to that of the treated trees, becoming actually better in the third experimental year.

The trend of the lines and the anatomical observations which will be discussed later suggest that no beneficial effect of treatments would be observed at the time when the renewing bark is tapped again.

Measurements e, h, l — Measurement e was taken one year after the commencement of the experiment at ½ inch above the tapping cut in December 1953 (T_1). Measurements h and l were taken at the same level in December 1954 (T_2) and December 1955 (T_3) respectively. The data are summarised in Table 4 and shown graphically in *Figure 6*.

Some effect due to treatment can already be observed at the time of measurement e (T_1) of the 14 days old renewing bark. Treatments *10, 11* and *12* (those containing 1% 2,4-D) start off from a slightly higher level than the others, thus suggesting an almost immediate effect of 2,4-D. This was not noticed in the comparable series of measurements in *Figure 5*, where measurement b was also taken ½ inch above the tapping cut but just before the first set of treatments was applied so that no treatment effect could have shown up. This therefore supports the theory of the immediate effect of 2,4-D at the time of measurement e.

TABLE 5. BARK THICKNESS MEASUREMENTS AT DECEMBER 1954 CUT LEVEL

Millimetres

Treatment	i (T_2) Thick	i (T_2) Effect	m (T_3) Thick	m (T_3) Effect
1 Control	3.70	0	3.93	0
2 SVP 2295C	3.67	–0.03	3.80	–0.13
3 Ensis 352	4.30	+0.60	4.72	+0.79
4 Otina C	4.10	+0.40	4.15	+0.22
5 Palm oil	4.22	+0.52	4.08	+0.15
6 PO + 0.02% 2,4-D	4.12	+0.42	4.07	+0.14
7 2295C + 0.02% 2,4-D	4.07	+0.37	4.25	+0.32
8 PO + 0.1% 2,4-D	3.77	+0.07	3.97	+0.04
9 2295C + 0.1% 2,4-D	4.13	+0.43	4.37	+0.44
10 PO + 1% 2,4-D	4.55	+0.85	5.40	+1.47
11 2295C + 1% 2,4-D	4.48	+0.78	5.70	+1.77
12 Stimulex	4.97	+1.27	5.80	+1.87

TABLE 6. MEAN NUMBER OF LATEX VESSEL ROWS IN BARK OF THIRD RENEWAL AND VIRGIN BARK

Samples taken at same level each year

Treatment	Age of bark: 1 yr. Dec. 1953	2 yr. Dec. 1954	3 yr. Dec. 1955	Virgin Dec. 1955
1 Control	8.1	10.0	10.8	22
2 SVP 2295C	7.8	9.3	12.1	28
3 Ensis 352	9.8	10.1	11.7	23
4 Otina C	9.1	11.0	12.3	29
5 Palm oil	9.0	9.0	12.1	27
6 PO + 0.02% 2,4-D	8.7	9.8	11.8	27
7 2295C + 0.02% 2,4-D	10.1	9.1	11.8	27
8 PO + 0.1% 2,4-D	9.3	9.5	12.0	24
9 2295C + 0.1% 2,4-D	7.3	10.0	11.1	23
10 PO + 1% 2,4-D	9.0	10.5	12.1	31
11 2295C + 1% 2,4-D	9.7	10.7	13.4	27
12 Stimulex	9.3	9.5	13.1	27

The treatment lines show the same pattern as observed in *Figure* 5, thus stressing the reliability of those observations. Almost all of the extra increase is obtained during the first year of renewal and several treatments show a downward trend in the second year.

Measurements i, m — These are shown in Table 5 and the treatment effect figures are plotted in *Figure* 7. Measurement i was taken in December 1954 (T_2) at 2 inches above the tapping cut and measurement m was taken at the same height in December 1955 (T_3). At position i renewing bark of approximately two months of age was measured, which served as a check on the suggested rapid effect of 2,4-D, found when measuring 14 days old renewing bark at position e (*Figure* 6). A marked effect due to treatment is observed on the two months old renewing bark for nearly all treatments, but especially for the formulations containing 1% 2,4-D. This observation therefore confirms that the effect of bark treatment is very rapid and that the observation made on the 14 days old renewing bark was not due to experimental error.

The high start of the Ensis 352 line is due to the fact that this mixture was replaced, as it ran out of stock, by a solution of 2,4,5-T in palm oil, reputed to be of 1% concentration. The outstanding effect of 1% 2,4,5-T formulations on yield and bark renewal as observed in other experiments makes the composition of this so called 1% 2,4,5-T in palm oil formulation rather doubtful. The downward trend of the three palm oil lines, respectively palm oil + 0.1% 2,4-D, palm oil + 0.02% 2,4-D, and palm oil, cannot be accounted for. The long storage of the formulations may have increased the free fatty acid content of the palm oil to an undesirable level.

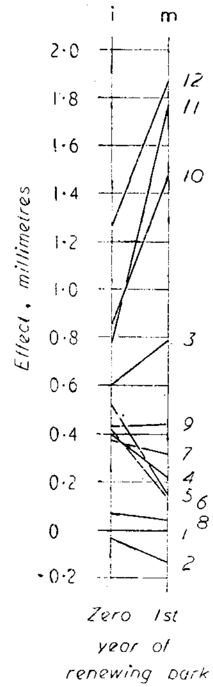

Figure 7. Treatment effects at December 1954 cut level.

To summarise the effect of bark treatments on the thickness of the renewing bark, all formulations have shown a beneficial effect on the thickness of the renewing bark; no additional effect has been observed as a result of the addition of 0.02% 2,4-D to Standard Vacuum product 2295 C or palm oil but some additional effect is suggested for the 0.1% concentration; all 1% concentrations of formulations containing 2,4-D (including Stimulex) have had a marked effect, which occurred mainly during the first year of renewal, in increasing the thickness of the renewing bark; the initial beneficial effect of bark treatments in increasing the thickness of the renewing bark occurs mainly during the first year of renewal and additional treatment seems to hinder subsequent renewal, so that trees not treated show a larger increase in thickness in subsequent years.

Anatomy of the Renewed Bark

It has been shown in the preceding section that several bark treatments have induced a significant increase in the thickness of renewing bark and the question arises whether this bark of increased thickness will have a better yield capacity than the non-treated thin bark of the control trees. A straightforward answer can be obtained by tapping the bark, but the thickness of the renewed bark of the control trees is as yet insufficient for tapping and this approach will have to be postponed for several years. An insight into the possible yield capacity can be obtained by microscopical examination of the anatomy of the renewing bark, assuming that within one clone the number of latex vessels is an indication of the yield capacity. This has been done at yearly intervals on six trees of each treatment and a summary of the count of latex vessel rows is given in Table 6.

Although there was a suggestion of a slight increase in the number of latex vessel rows in the treated bark, no significant difference could be established and it is concluded that none of the treatments had either a depressing or an improving effect on the cambium in the formation of latex vessels. The extra thickness of the treated bark occurs in the outer bark layers which contain no latex vessel and is very apparent in bark treated with formulations containing 1% 2,4-D (*Figure* 8).

These observations suggest that treatment with formulations for stimulating bark renewal will not result in an increased yield capacity of the renewing bark, but that the increased thickness may give a better support to the tapping knife. The occurrence of several phelloid like layers, however, make it probable that much of the extra thickness will flake off when the tapping knife cuts through the bark. This has already been experienced to a disturbing degree when bark samples for microscopical investigation were being collected.

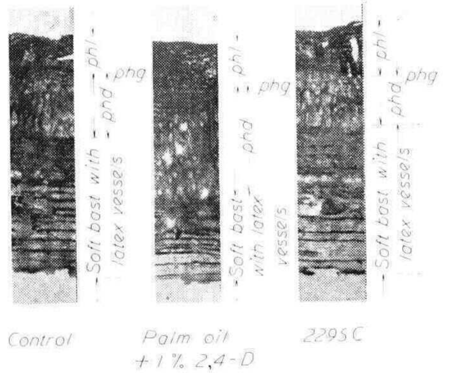

Figure 8. *Longitudinal section through three year old renewing bark.*
phg phellogen phd phelloderm phl phellem

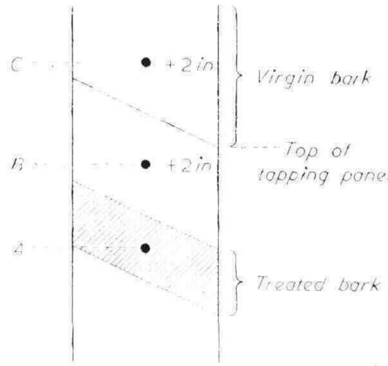

Figure 9. *Bark samples were taken at A at the centre of the treated bark, at B 2 inches above the treated bark, and at C 2 inches above the tapping panel.*

We have been fortunate in receiving a request, from the Director of Research of the Chemara Research Station at Seremban, for a microscopical examination of bark samples which had been treated with the yield stimulant Stimulex, which contains 2,4-D. We were given permission to publish the results of this experiment which links up closely with our stimulation of bark renewal experment under review. Buddings of clone PB 86 planted in 1938, had been treated in November 1935 with Stimulex on a three inch strip of renewing bark immediately above the tapping cut. In December 1955 the treated bark was stated to be approximately twice the thickness of the renewed bark immediately above the treated area, although showing no damage. Samples were collected from five treated and five control trees of similar girth at places indicated in the diagram in *Figure* 9. The results of our examination are summarised in Table 7. The detailed figures show a larger variation within than between treatments with regard to the number of latex vessel rings and the thickness of the soft bast and the suggestion of a slightly higher number of latex vessels and of a slightly thicker soft bast of treated trees is therefore not proven.

The 7.1 mm thick (9.3 to 2.2 mm) non latex containing layer of bark at the *A* position of the trees is expected to hinder subsequent renewal. This gradually lignifying periderm tissue is not expected to possess the ability to dilate which is shown by medullary rays in normally renewing bark. Deep cracks might therefore be expected to appear if the activity of the cambium remains normal, but in our stimulation of bark renewal experiment it is already suggested that the increase in bark thickness of treated trees is slower in later years than that of the non-treated control trees. The samples taken at position *B*, two inches above the treated strip of bark, also show an increased thickness which shows that the growth stimulating effect of 2,4-D is not localised at the place of application.

A similar observation has already been made on trees treated with a yield stimulant on a three inch wide strip of scraped bark below the tapping cut, where it was found that the thickness of the renewing bark had been increased significantly. Microscopical examination of the bark samples did not reveal any change in the number of latex vessel rows (DE JONGE 1955).

It is interesting to note that the diameter of the latex vessels has not been changed by application of the yield stimulant so that the increased rate of latex flow cannot be explained by increase in diameter of the latex vessels. In time we may be in a better position to judge the merits of this method of stimulating bark renewal but at the present stage of research it would appear that no yield stimulants should be applied above the tapping cut on trees of which the renewing bark is to be tapped in future.

It is also doubtful whether treatment of a tapping panel with so called bark renewal stimulants which do not contain hormones or synthetic growth substances is an economical proposition except for wound treatment. Planting material at present recommended is capable of satisfactory bark renewal if proper upkeep and manuring of the fields are maintained, not only during the period of immaturity but also during later years of tapping. There would be need for a period of regular tapping panel treatment only in the case of outbreaks of fungal diseases. Such diseases can be controlled with the recommended fungicides if applied at a sufficient frequency to the newly tapped bark.

Yield

The yield was recorded by coagulation of the latex in the cups of all trees once a week. The cup lumps of each plot were collected monthly, air dried for one month and weighed. No correction has been made for the water content remaining after drying. Recording was done over two months before the experiment was commenced and was continued after application of the first set of treatments throughout the three years duration of the experiment.

TABLE 7. SAMPLES OF TWO YEAR OLD RENEWED BARK

PB 86 Buddings, Treated and Control

Trees	Bark thickness, mm			Latex vessel rings		
	A	*B*	*C*	*A*	*B*	*C*
Treated	9.3	5.6	7.6	15.5	15.6	22.9
Control	4.1	4.3	7.9	14.7	14.4	23.0

Trees	Soft bast, mm			Diameter of latex vessels at *A*		
	A	*B*	*C*			
Treated	2.2	2.2	3.9	19.6	to	21.6 mu
Control	1.9	1.8	3.6	19.2	to	22.8 mu

The soft bast contains the latex vessels. Sampling positions *A*, *B* and *C* are shown in Figure 9

TABLE 8. YIELD RECORDS

Treatment	Pre-treatment mean yield gm/tree/tap	First year 1952-3: Post-treatment mean yield gm/tree/tap	First year 1952-3: Adjusted post-treatment mean yield gm/tree/tap	First year 1952-3: Adjusted post-treatment as % of control	Second year 1953-4: Post-treatment mean yield gm/tree/tap	Second year 1953-4: Adjusted post-treatment mean yield gm/tree/tap	Second year 1953-4: Adjusted post-treatment as % of control	Third year 1954-5: Post-treatment mean yield gm/tree/tap	Third year 1954-5: Adjusted post-treatment mean yield gm/tree/tap	Third year 1954-5: Adjusted post-treatment as % of control
1 Control	20.6	15.6	15.0	100	18.0	17.3	100	23.4	22.7	100
2 SVP 2295C	19 5	15.8	16.3*	109	15.6	16.1	93	20.4	20 9	92
3 Ensis 352	18.4	13.4	14.9	100	14 9	16.4	95	22 4	24 1	106
4 Otina C	22.9	18.7	15.9	106	19.7	16.8	97	26.4	23.4	103
5 Palm oil	18.6	15.5	16 8**	112	17.2	18.5	107	24.9	26.2	115
6 PO + 0.02% 2,4-D	17.3	14.5	17.0**	114	13 8	16.5	95	19.3	22.0	97
7 2295C + 0.02% 2,4-D	20.7	17.0	16.3*	109	18.6	17.9	103	24.1	23.4	103
8 PO + 0 1% 2,4-D	20.1	18.3	18 2***	121	16.5	16.4	94	18.6	18.5	82
9 2295C + 0.1% 2,4-D	19.0	16.3	17.3**	115	18.2	19.2	111	22.4	23.4	103
10 PO + 1% 2,4-D	16.9	22.5	25.5***	170	22.6	25.6***	148	24.9	28.1*	123
11 2295C + 1% 2,4-D	20.0	21.7	21.7***	145	21.5	21.5*	124	26.8	26.8	118
12 Stimulex	25.9	30.3	24.7***	165	28.7	22.9**	132	35.1	29.1*	128
s.e. adjusted post treatment means			±0.47			+1.18			±1.74	
Min. 5% significant difference *			1.3			3.3			4.9	
Min. 1% significant difference **			1 8			4.4			6 6	
Min. 0.1% significant difference ***			2.3			5.8			8.5	

A summary of the yield records, statistically analysed, is given in Table 8. Highly significant increases in yield have been obtained during the first experimental year by those treatments which contained either 0.1 or 1% concentration of 2,4-D (including Stimulex). The best results were noted for the formulations containing 1% 2,4-D. Noticeable increases were also obtained with palm oil only and with palm oil plus 0.02% 2,4-D; although the addition of this low concentration of 2,4-D did not give an additional effect on yield. Both these treatments reached the 5% level of significance.

An increased yield at the 5% level of significance was obtained by treatment with Standard Vacuum product 2295 C and again the addition of the low 0.02% concentration of 2,4-D had no additional effect on yield. The yield stimulating effect of palm oil was not unexpected as it had been shown previously (BEELY & BAPTIST 1939) that increased yields were obtained if it was applied to the scraped bark below the tapping cut. This effect was attributed to the presence of hormones in this vegetable oil. Standard Vacuum product 2295 C however is a petroleum grease of the vaseline type of which an analysis has been carried out at the Department of Agriculture and Horticulture of the University of Bristol by Mr G. V. Coles, who reported:

The product was a stiff brownish grease with an odour of refined residual petroleum. Over the temperature range 40°-50°C it gradually softened to a viscous brown oil with a green bloom. Analysis showed a trace of sulphur (about 0.01%) and ash (about 0.01%). The small amount of ash contained iron, copper, and zinc. Nitrogen, phosphorus, halogen, boron and mercury were absent. There was present only a trace (less than 0.01%) of acidic materials soluble in aqueous caustic soda. These were non phenolic in nature.

The product was analysed for C and H (at Oxford) and a commercial petrolatum ('vaseline') was included for comparison. The results were:

	Carbon %	*Hydrogen %*	*Total*
2295 C	86.19	13.74	99.63
Commercial petrolatum	86.30	13.61	99.91

Dr L. C. Luckwill, also of Bristol, in order to find if any growth substances were included in this preparation which shows such a beneficial effect on wood healing, carried out the standard coleus leaf abscission test, which gave a negative result.

The reason for the observed increase in yield by monthly treatment of the bark above the tapping cut with Standard Vacuum product 2295 C would therefore appear to be the provision of a protection against drying out of the thin layer of bark remaining after tapping, which results in a more rapid formation of a cork cambium and subsequent periderm tissue. The trace of sulphur and ash are not expected to have influenced the yield. As however, the yield increase just reaches the minimum of the 5% significant difference level and the treatment concerned is one out of twelve, the yield increase is by no means established with certainty and as the possible effect is completely lost in subsequent years, it would serve no useful purpose to go further into this observation. The downward trend of response to treatment in successive years is striking and is well demonstrated in *Figure 11*, which shows the mean adjusted monthly yields of the three experimental years for treatments *1* and *12*, respectively control, and Stimulex.

This downward trend seems to be a feature of repeated applications of yield stimulants and has also been noted when they were applied at half yearly intervals on the three inch strip of scraped bark below the tapping cut on mature buddings and seedlings. With this method however, we have not observed a drop of yield to below the level of the non-treated control trees.

The application of formulations containing 1% 2,4-D (treatments *10*, *11* and *12*) in this experiment, in which application was made monthly above the tapping cut, has not resulted in a drop below control level either, and although there is distinct downward trend of the yield as time progresses, the yield is still some 20% above the control level during the third experimental year. It is not fully understood why treatment 9 (palm oil plus 0.1% 2,4-D) caused the yield to drop below that of the non-treated trees after giving a satisfactory increase during the first year.

The finding that it was possible to increase the yield of *Hevea brasiliensis* with monthly applications of yield stimulating formulations above the tapping cut has been followed up in further experiments on budded and seedling material and has been compared with the standard method of application of a yield stimulating mixture at intervals of six months to three inch wide strip of scraped bark below the tapping cut. As shown below, satisfactory yield increases have been obtained, but applications above the tapping cut invariably resulted in a very uneven bark renewal. An attempt was made to overcome this trouble by including a lower concentration of the growth substance in the carriers and later by using more suitable brushes for application.

The results of four experiments, one carried out on clonal seedlings and two on unselected seedling trees and one on budded trees follow.

Clonal Seedling Experiment, Planted 1930 —The following treatments have been included:

- A Palm oil plus 1% 2,4,5-T monthly application above the tapping cut
- B Palm oil plus ½% 2,4,5-T monthly application above the tapping cut
- C Palm oil plus 0.1% 2,4,5-T monthly application above the tapping cut
- D R.R.I. yield stimulant monthly application above the tapping cut
- E Stimulex monthly application above the tapping cut
- F R.R.I. yield stimulant applied to 3 inch strip of scraped bark below the cut at 6 months intervals
- G Control

Yield records covering a period of six months are given in Table 9.

TABLE 9. CLONAL SEEDLING YIELD RECORDS

Mean monthly yields in grams per tree per tapping

Treatment	A	B	C	D	E	F	G
Pre-treatment (2 months)	37.9	37.1	33.7	36.1	38.4	36.2	36.8
1st month	51.1	46.2	34.9	49.6	57.8	67.8	40.4
2nd month	54.5	53.6	42.9	58.9	55.2	53.8	44.4
3rd month	49.3	51.1	41.6	57.5	57.8	44.7	42.0
4th month	48.8	54.6	45.8	63.7	59.3	48.4	45.8
5th month	45.2	53.4	46.9	58.9	61.4	49.6	49.2
6th month*	38.3	46.8	42.7	52.6	50.2	41.5	39.5
Mean 6 months	47.9	51.0	42.5	56.9	57.0	51.0	43.6

* wintering

The superiority of the two commercial yield stimulating formulations, treatments D and E, is well brought out, and also the fact that application above the tapping cut has induced a higher overall yield than application below the tapping cut (treatment *F*) which latter gave a high initial increase followed by the familiar downward trend to slightly above control level. All treatments which were applied above the tapping cut, except treatment *C* which contained only 0.1% 2,4,5-T and failed to induce a yield increase, have resulted in a very irregular and undesirable bark renewal. This method of yield stimulation should therefore not be used if any interest is taken in renewing bark with regard to future tapping. It has the advantages that no bark scraping is required and that the yield trend is less irregular than with application of a yield stimulant below the cut.

No yield records are yet available from the experiment, which continues, using a new type of brush to enable a thinner application of the stimulant. The bark renewal appears now to be much better, but it is expected that there will be a decrease in yield response.

Unselected Seedling Experiments, Planted 1930 — In these experiments monthly application of a yield stimulant above the cut is compared with half yearly application below the cut on trees tapped alternate daily either on a low cut in bark of second renewal or on a high cut in the virgin bark. The following treatments have been compared:

H S/2.d/2.100% tapping on low cut in bark of second renewal
K as *H*, with a stimulant below the cut once in 6 months
L as H, with monthly application of a stimulant above the cut
M V/2.d/2.100% tapping on a high cut in the virgin bark
N as M, with a stimulant below the cut once in 6 months
O as M, with monthly application of a stimulant above the cut

The yields during the first six months of this experiment are summarised in Table 10. This experiment again shows that yield stimulants applied below the cut on

TABLE 10. COMPARISON BETWEEN STIMULANT APPLICATION ABOVE AND BELOW THE CUT

Mean monthly yields in grams per tree per tapping

Treatment	*H*	K	L	*M*	*N*	O
Pre-treatment (2 months)	15.9	14.2	15.4	15.6	15.5	15.4
1st month	18.0	36.4	16.9	18.6	49.6	27.3
2nd month	22.0	26.8	21.9	20.6	34.7	27.1
3rd month	22.2	19.0	27.0	21.8	31.0	27.7
4th month	22.9	17.8	27.3	20.8	31.3	30.3
5th month	22.4	18.9	28.0	22.3	28.1	32.1
6th month*	21.1	18.2	26.9	20.2	25.2	29.0
Mean 6 months	21.4	22.9	24.7	20.7	33.3	28.9

* wintering

thin renewed bark lead to disappointing results, with the increase in yield lasting for a short time and the yield dropping below the level of trees not treated (treatment *H*).

Treatment above the cut on bark of third renewal also gave disappointing results, although the yield is consistently higher than that of the control trees. Treatment below the cut in virgin bark (treatment *N*) has given a distinct increase in yield and the response to treatment above the cut (treatment O) was also satisfactory. Under the conditions of this experiment it was three months before the yield level of treatment O caught up with that of treatment *N*. In other experiments this occurred in the first or second month after treatment. The bark renewal of the trees treated above the tapping cut was again very uneven.

Further Unselected Seedling Experiment, Planted 1930 — The following treatments have been compared:

P S/2.d/2.100% tapping in bark of second renewal
Q V/2.d/2.100% tapping in virgin bark
R as Q, with a stimulant below the cut once in 6 months
S as Q, with monthly application of a stimulant above the cut

The results of the first six months of this experiment are summarised in Table 11. The superiority of the monthly treatment above the tapping cut is well brought out in this experiment and the yield on treatment *S* was similar to that of trees treated below the tapping cut as early as the first month of the experiment.

TABLE 11. OTHER COMPARISON BETWEEN STIMULANT APPLICATION ABOVE AND BELOW THE CUT

Mean monthly yields in grams per tree per tapping

Treatment	*P*	*Q*	*R*	*S*
Pre-treatment (2 months)	13.3	14.6	13.3	14.4
1st month	13.0	17.6	31.7	32.1
2nd month	17.6	17.9	20.6	26.5
3rd month	12.1	14.7	18.1	27.1
4th month	15.1	16.6	20.1	31.7
5th month	15.0	15.8	18.5	31.3
6th month*	14.7	15.1	17.1	32.3
Mean 6 months	14.6	16.3	21.0	30.2

* wintering

The treatments mentioned in Tables 10 and 11 all serve as control treatments in experiments carried out in these fields in which intensive tapping systems are tried out. These experiments will continue for several years and will therefore give a long term comparison between application above the tapping cut and below the tapping cut.

Short Term Experiment on Mixed Buddings of AVROS 50 and Pil D65 — In the abovementioned experiments yield recording was carried out by coagulating the latex in the cup on each tapping day. The cup lumps were strung on a wire, hung on the trees and collected once a month for drying and weighing. In the experiment using budded trees of clones AVROS 50 and Pil D 65 recording was done by measuring the latex obtained at each tapping so that a day to day yield trend could be recorded. The typical yield trends for both treatments are demonstrated in the graph plotted from the data of this experiment (*Figure 10*), and are confirmed by the data of all the earlier experiments mentioned.

None of the experiments in which a comparison is made between applications above and below the cut has been running for more than six months. The effect of treatment above the tapping cut over a period of three years can be studied in the stimulation of bark renewal experiment under review. The commercial yield stimulating mixture Stimulex has been applied above the tapping cut, monthly without interruption throughout three years in the experiment, and the effect on the yield is given in *Figure 11*. The actual yield figures can be seen in Table 8, treatment *12*.

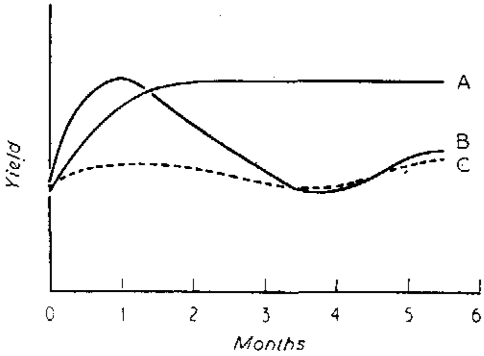

Figure 10. Yield trend after application of Stimulex above or below the cut.

A *above cut* B *below cut* C *control*

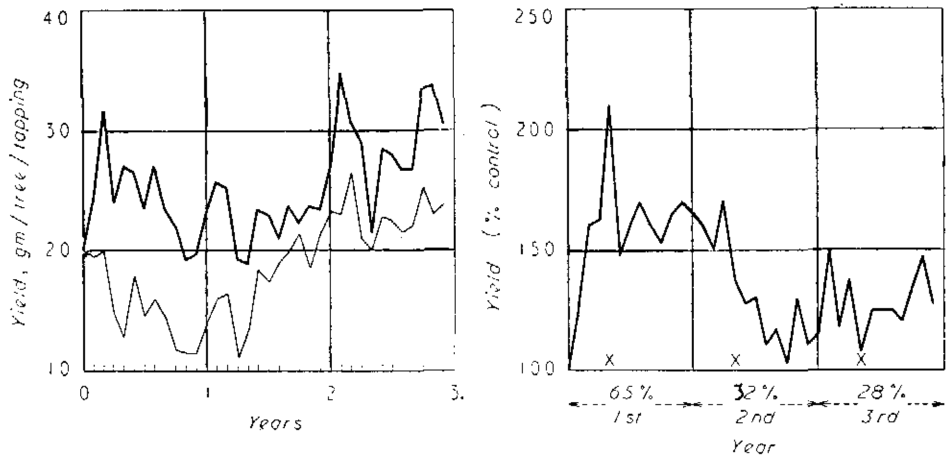

Figure 11. Yield trend on application of Stimulex above the cut.
Left: Lower plot is control. Right: X signifies wintering.

The yield trend of both treated and control trees is irregular, but both follow approximately the same pattern. There is a downward response to the yield stimulant in the second year and a slow improvement appears in the third year. The downward response to yield stimulants has also been observed after repeated half yearly applications of stimulant to the scraped bark below the cut as illustrated in *Figure 12*. The histogram covers a period of three years during which six successive applications have been given at half yearly intervals. The lowered yield responses appear to be characteristic of repeated yield stimulant applications, but there is evidence that further high yield increases will be obtained after change over of the tapping cut to the other side of the trees; similar decreases after successive applications of the stimulant may, however, be expected.

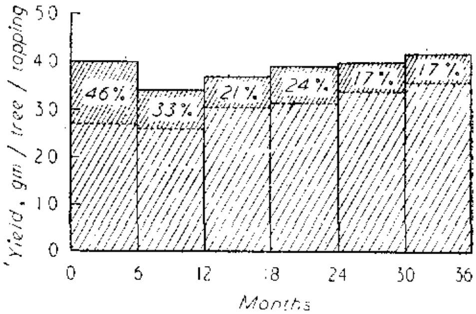

Figure 12. Yield trend on application of Stimulex below the cut.

The yield has not dropped below control level in any experiment except the one which was carried out on low yielding old unselected seedling trees with very thin renewed bark (Table 10 treatment K).

From the above experiment it appears that monthly application of a yield stimulant above the tapping cut to the thin film of bark left after tapping during the preceding month is a highly satisfactory method of increasing the yield of rubber trees. There is much evidence to suggest that this method results in a higher overall yield increase than the standard method of half yearly application of the yield stimulant below the tapping cut. Long term comparisons between the two methods are in progress.

The thickness of the renewing bark becomes markedly increased if the stimulant is applied above the tapping cut, but the renewal is very irregular. We cannot yet, therefore, recommend this method of yield stimulation if further interest is to be taken in the bark left after tapping for future exploitation. Experiments are in progress to improve the method of application to overcome the disadvantage of irregular bark renewal.

Girth

From the above discussion of the effect of stimulants on yield, the question arises whether the increased yield level affects girthing. Girth measurements were taken at a height of 60 inches from the union of all trees included in the stimulation of bark renewal experiment in December 1952 and a second series of measurements was taken in December 1955. On these slow growing trees, the bulk of which occur in experimental planting systems where tree density is high, no influence of the treatments on the girthing of the trees could be detected.

Experiments are now in progress on vigorously growing young planting material. One of these experiments uses Prang Besar Further Proof seedlings planted in November and December 1949. Tapping commenced on 1 May 1956 and a yield stimulant was applied on 1 June to a three inch strip of scraped bark below the half spiral tapping cut. Girth measurements are being taken at six months intervals and the measurements taken in October 1956 showed the following girth increments from April to to October 1956: control trees 1.18 inches; stimulated trees 0.90 inches. The difference of 0.28 inches is significant at the 5% level.

Experiments with clonal and unselected seedlings have not revealed a retarding effect on growth due to repeated application of a yield stimulant either above or below the cut and it is recommended that the use of a yield stimulant be limited to material of which at least the virgin bark of the normal tapping panels has been tapped away. Treatment of bark above the tapping cut is not recommended if the treated bark is considered for tapping in future.

SUMMARY

An experiment has been described which was designed to compare the effects on bark renewal of vegetable and mineral oils, with and without the addition of 2,4-D, and the results are presented in tables and graphs. All treatments had an initial beneficial effect on bark renewal but highly significant results were obtained only from treatments containing 1% 2,4-D. It is apparent that the beneficial effects of the treatments occurred mainly in the first year and to a lesser extent in the second year. Subsequently the renewed bark of the control trees thickened at a greater rate.

The increased thickness of renewed bark as a result of the treatments appeared to be due solely to activation of the cork cambium. No increase of lactiferous tissue was noted.

Although the experiment under review was designed to compare the effects of the treatments on bark renewal, the increases in yield resulting from the treatments led to an intensive study of this aspect. The yield records from the experiment have been presented and discussed.

Notes have been presented on further experiments which extend the investigation into the possibility of employing yield stimulants above the tapping cut. These experiments are not yet complete but it seems unlikely that such applications can be usefully employed when the resulting renewed bark is to be tapped.

I am indebted to Mr D. R. Westgarth for advice in the design of experiments and analysis of results. I express my thanks to Dr E. D. C. Baptist, former Head of the Botanical Division, who took an active part in planning and laying out the stimulation of bark renewal experiment. The able assistance of Mr T. S. Ayar who was in charge of the field work, of Mr Lee Choo Beng who compiled experimental data, and of Mr Chen Khyun Thai who compiled experimental data and prepared the bark sections for microscopical examination, is gratefully acknowledged.

Botanical Division
Rubber Research Institute of Malaya
Kuala Lumpur *May*

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