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Residual Effects of Ground Cover and Nitrogen Fertilisation of Hevea prior to Tapping

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Leguminous ground covers maintained until the rubber trees came into tapping have a residual beneficial effect on their yield. Over the ten years of experimental tapping, trees in leguminous cover plots yielded 14 364 pounds of rubber per acre — 20% more than those grown in natural cover plots. Also, thickness of renewed bark in ex-leguminous plots was 6 to 9% better than in the natural cover plots.

Examination of tree root systems after ten years of tapping showed that root development in interrows was 37% more prolific where previously there had been leguminous rather than naturally established non-leguminous covers. Measurements of tree trunk growth rates, tree canopy, soil and leaf nutrient status, however, did not show any relationship to previous cover type and nitrogen application treatments to the trees during immaturity.

Continuous application of nitrogen during immaturity did not appear to have affected tree root development, but in natural cover plots it improved yield.

Over the years an increasing negative interaction on yield has been established between the residual effects of nitrogen fertilisation in leguminous cover plots and Mikania cordata *weeding policy. This was in part related to quality of bark renewal but not to tree root development.*

If optimum rubber tree growth is desired, and at the time of planting soil nitrogen status is low or physical structure poor, then Malayan work has established a marked need for a vigorous leguminous ground cover such as *Pueraria phaseoloides* can provide (MAINSTONE, 1961; WATSON, 1961 and 1963; MAINSTONE AND WONG, 1966).

This paper refers to an experiment of eight randomised blocks allowing investigation of the interactions and main effects of natural *versus* leguminous covers and discontinued *versus* continued levels of nitrogen fertilisation of trees prior to tapping. The continuous level of nitrogen fertilisation, using ammonium sulphate, was similar to that then normally recommended for commercial areas on Dunlop estates. The experiment was budded with PB 86 in 1951 and the site was an area of poisoned old seedling rubber. Soil was a transition Batu Anam/Malacca series type of moderately good quality.

Published findings (MAINSTONE, 1961) established that trees grown in association with a sown leguminous cover became tappable, according to estate standards, twelve months earlier than where a natural non-leguminous ground cover had been allowed to regenerate. The effect of continuing nitrogen fertilisation with ammonium sulphate until trees became tappable, rather than discontinuing it eighteen months after budding when trees were branched and considered to be well established, varied with cover type. In the presence of leguminous covers, the effect was small and not significant but in plots with a naturally regenerated non-leguminous cover, it brought trees to a sufficient girth for tapping seven months earlier.

The early yield data, along with details of experimental technique, indicated an advantage from having had a leguminous cover (MAINSTONE, 1963a and b).

Here data from ten years of exploitation are presented in relation to yield, trunk growth,

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TABLE 1. MEAN YIELDS PER ACRE IN POUNDS NO.1 + NO.2 GRADES DRY RUBBER OVER TEN YEARS OF TAPPING* WITHIN THE EXPERIMENT

Year	Mean	Treatments						Main effects							Significance of interaction
		Low nitrogen		High nitrogen		S.E.	P	Low N	High N	P	Nat.	Leg.	P	S.E.	
		Nat.	Leg.	Nat.	Leg.										
1	156	0	255	30	337	22	< 0.001	127	183	< 0.05	15	296	< 0.001	15	N.S.
2	591	191	818	550	802	50	< 0.001	504	676	< 0.01	370	810	< 0.001	35	< 0.01
3	1 073	876	1 212	1 030	1 175	36	< 0.001	1 044	1 102	< 0.20	953	1 193	< 0.001	25	< 0.05
4	1 230	1 009	1 348	1 198	1 363	33	< 0.001	1 179	1 281	< 0.01	1 104	1 356	< 0.001	23	< 0.05
5	1 318	1 134	1 437	1 285	1 416	25	< 0.001	1 285	1 350	< 0.05	1 209	1 426	< 0.001	18	< 0.01
6	1 614	1 482	1 680	1 652	1 640	35	< 0.01	1 581	1 647	< 0.10	1 567	1 660	< 0.05	25	< 0.01
7	1 698	1 469	1 829	1 676	1 816	48	< 0.001	1 649	1 746	< 0.10	1 572	1 823	< 0.001	34	< 0.05
8	1 666	1 437	1 774	1 639	1 813	45	< 0.001	1 605	1 726	< 0.05	1 538	1 793	< 0.001	32	< 0.10
9	1 819	1 635	1 886	1 795	1 960	52	< 0.001	1 760	1 878	< 0.01	1 715	1 923	< 0.001	37	N.S.
10	*2 012*	*1 879*	*2 051*	*2 010*	*2 108*	*57*	*< 0.10*	*1 944*	*2 079*	*< 0.20*	*1 965*	*2 059*	*< 0.05*	*40*	N.S.
1 to 10	13 178	11 116	14 294	12 869	14 434	M.S.D.† 988 1 344 1 814	 0.05 0.01 0.001	12 705	13 651	ca 0.01	11 992	14 364	< 0.001	237	< 0.05

*Tapping system: S/2.d/2.100%
† Mininum significant difference.

bark renewal thickness, root development and wintering patterns. Special reference is made to the importance of nitrogen fertilisation and *Mikania cordata* weeding policy in leguminous cover plots.

EXPERIMENTAL AND RESULTS

Yields

General. For the ten years of tapping reviewed, the method of estimating yield has been identical to that previously employed (MAINSTONE, 1963a). In this paper reference is only made to yield per acre and two methods of presentation are employed:

(A) Yield in relation to successive years of tapping within the experiment. Data have direct commercial significance.

(B) Yield in relation to successive years of tapping within individual plots. This method of presentation has mainly academic importance. In view of the two years which were required to bring all plots into tapping, yields over eight years are considered.

Yield according to Method (A)—successive years of tapping in the experiment. Table 1 shows that trees grown in association with leguminous covers outyielded the others by 20%. The advantage of having had a leguminous cover falls off with time. This is seen from the regression presented in *Figure 1.* Other regressions on the full analysis of data lacked statistical significance but in view of the interaction shown in *Table 1*, another approach was taken. The extra mean crop yields from both classes of leguminous cover plot above those from the natural cover high nitrogen plots were calculated by years. From this data, the regression $Y = 245.7 - 17.5X$ was obtained where Y = extra yield in pounds per acre and X = year of tapping. The advantage from the leguminous cover is thus less but the pattern of fall-off of advantage is similar, 228 pounds in the first year to 71 in the tenth.

So far presentation has not taken into account that in half of the eight experimental blocks, *Mikania cordata* was hand-weeded from leguminous cover plots. Weeding commenced at twenty-four months after budding and continued until the start of tapping. Accordingly, a separate analysis of data from leguminous cover plots was carried out. A strong negative interaction between weeding policy and level of nitrogen fertilisation was established and is given in *Table 2.* The regression with years shown in *Figure 2* demonstrates that the magnitude of the negative interaction increases with time.

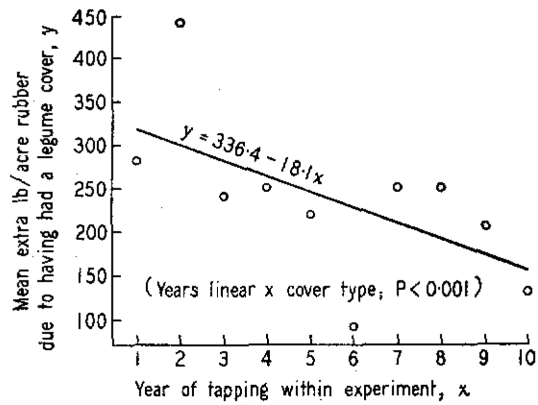

Figure 1. Regression of yield advantage from legume covers by years of tapping within the experiment.

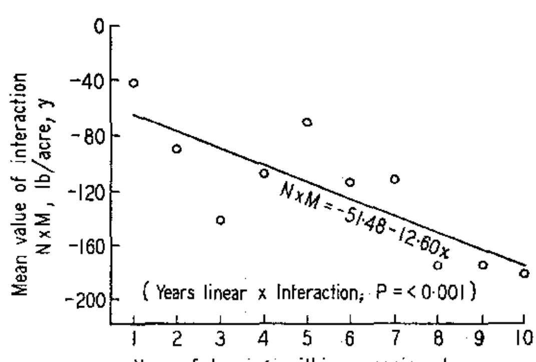

Figure 2. Relationship of mean nitrogen level × M. cordata *weeding policy in leguminous cover plots on yield per acre by years of tapping within the experiment.*

TABLE 2. MEAN YIELDS PER ACRE IN POUNDS NO.1 + NO.2 GRADES DRY RUBBER OVER TEN YEARS OF TAPPING IN THE EXPERIMENT: LEGUMINOUS COVER PLOTS ONLY

Year	Main effects								Interaction effect of *M. scandens* weeding policy × nitrogen level during immaturity	
	M. scandens weeding policy				N level					
	In	Out	S.E.	P	Low	High	S.E.	P	Effect	Significance (P value)
1	284	309	60	N.S.	256	338	43	N.S.	− 41	N.S.
2	804	816	39	N.S.	818	802	32	N.S.	− 90	< 0.10
3	1 169	1 219	66	N.S.	1 212	1 176	25	N.S.	− 142	< 0.01
4	1 390	1 321	36	N.S.	1 348	1 364	19	N.S.	− 107	< 0.01
5	1 458	1 396	20	< 0.20	1 437	1 416	30	N.S.	− 70	< 0.20
6	1 636	1 685	24	N.S.	1 681	1 640	19	N.S.	− 113	< 0.01
7	1 809	1 837	76	N.S.	1 830	1 816	29	N.S.	− 111	< 0.05
8	1 802	1 786	88	N.S.	1 775	1 813	27	N.S.	− 177	< 0.01
9	1 962	1 884	62	N.S.	1 886	1 960	37	N.S.	− 176	< 0.05
10	2 131	2 029	82	N.S.	2 051	2 109	16	< 0.05	− 180	< 0.001
1 to 10	14 445	14 282	485	N.S.	14 294	14 434	215	N.S.	−1207	< 0.01

Yield according to Method (B)—successive years of tapping in individual plots. Comparisons of the yields obtained over the eight years according to treatments are presented in *Table 3*. Leguminous cover plots and those plots involving natural covers with the high level of nitrogen fertilisation did not produce significantly different total crops over the eight years reviewed. Yields were between six and ten per cent greater than those from the natural cover low nitrogen treatment plots.

Although the effect of *M. cordata* weeding in leguminous cover plots was investigated, the picture obtained was almost identical to that from investigating yields according to Method (A). This is doubtless due to the fact that all leguminous cover plots came into tapping over a short period of time.

Yield uniformity and influence of thinning stands. Prior to both the second and third rounds of thinning in individual plots and in order to assist choice of trees to be thinned in each plot, three rounds of individual tree yield recordings occurred. These rounds occurred outside periods of defoliation and separated by intervals of not less than one calendar month. Recordings were on normal tapping days. In addition, a further series of individual tree yield recordings took place in the ninth year of tapping in the experiment. On the data obtained, coefficients of variations of yield were calculated while, in respect of actual thinnings, immediate losses in crop have been estimated. Relevant significant findings are presented in *Table 4*. This shows a greater tree-to-tree yield variation in natural cover plots and as a result the estimated immediate losses in crop resultant from thinning stands will be greater in leguminous cover plots.

Girth Measurements and Related Data

Summarised findings relating to trunk development since the commencement of tapping within the experiment are contained in *Table 5*. The top three lines refer to girth measurements and from them it will be seen that absolute differences between treatments have diminished with time. This is due in part, firstly to the influence of variable times of opening up plots for tapping and secondly to thinning operations improving the regularity of stands in natural cover plots. The bottom two lines for relative growth rates give a more meaningful assessment of trunk growth as data are based upon common trees and the rate of increase in trunk sizes. Here the points of interest are (1) the lack of any residual effect of nitrogen fertilisation; (2) the final non-significance of the influence of previous cover type; and (3) the lack of any significant interactions between treatments.

Tree Heights

In the middle of the fourth year of tapping in the experiment, trees in legume plots were 2.8 feet higher than those in natural cover plots ($P < 0.01$) while the increase due to the high level of nitrogen fertilisation was only 2.2 feet higher ($P < 0.05$) (MAINSTONE, 1963a). Mean tree height was 62.5 feet. Six years later it had increased to 80.2 feet and there were no significant differences between treatments. Rate of increment in height over the six years averaged to 2.9 feet per year.

Foliage Density Measurements

About the time of commencing tapping there were big differences in foliage density, legume covers having allowed trees to carry much more leaf than did natural covers (MAINSTONE, 1961). In the tenth year of tapping however, using the same techniques of measurement as previously, differences due to previous treatments were not apparent.

Leaf Analysis

Leaf has been sampled on various occasions and the absolute levels of all nutrients for which analyses have been carried out have been acceptable irrespective of previous experimental treatments. Significant differences in levels for various nutrients have been found from time to time according to treatments. The absolute differences were always small and in practice could not be interpreted and so have been ignored.

Bark Renewal

Detailed bark renewal measurements were taken during the tenth year of tapping in the experiment. Measurements have been fully

TABLE 3. MEAN YIELDS PER ACRE IN POUNDS NO. 1 + NO. 2 GRADES DRY RUBBER OVER THE FIRST EIGHT YEARS OF TAPPING IN INDIVIDUAL PLOTS IN THE WHOLE EXPERIMENT

Year	Mean	Treatments						Main effects							Significance of interaction
		Low nitrogen		High nitrogen		S.E.	P	Low N	High N	P	Nat.	Leg.	P	S.E.	
		Nat.	Leg.	Nat.	Leg.										
1	689	723	682	726	626	19	<0.01	702	676	N.S.	724	679	<0.01	14	N.S.
2	987	902	1 057	981	1 006	31	<0.05	979	993	N.S.	941	1 033	<0.01	22	<0.05
3	1 134	1 025	1 228	1 122	1 157	28	<0.001	1 126	1 139	N.S.	1 073	1 192	<0.001	20	<0.01
4	1 302	1 294	1 314	1 289	1 311	31	N.S.	1 306	1 300	N.S.	1 291	1 312	N.S.	22	N.S.
5	1 477	1 387	1 495	1 551	1 474	32	<0.05	1 441	1 512	<0.05	1 469	1 484	N.S.	23	<0.01
6	1 521	1 352	1 643	1 552	1 537	37	<0.001	1 497	1 544	N.S.	1 452	1 590	<0.01	26	<0.001
7	1 573	1 430	1 667	1 531	1 663	44	<0.01	1 548	1 597	N.S.	1 480	1 665	<0.001	31	N.S.
8	1 710	1 706	1 696	1 697	1 738	52	N.S.	1 701	1 717	N.S.	1 701	1 717	N.S.	37	N.S.
1 to 8	10 393	9 821	10 784	10 452	10 515	M.S.D. 551	0.05	10 302	10 483	N.S.	10 136	10 650	<0.05	133	—

TABLE 4. YIELD VARIABILITY WITHIN STANDS AND THINNING DATA

Time and thinning intensity	Percentage coefficient of variability of yield based upon three rounds of individual tree yield recording				Assessment of immediate loss of crop due to thinning*			
	Natural cover	Legume cover	P	S.E.	Natural cover	Legume cover	P	S.E.
After $2\frac{1}{2}$ years of tapping in individual plots—thinning from 140 to 125 trees per acre; 10.7% of stand	46.1	33.4	<0.001	1.7	2.9	3.2	N.S.	0.5
After 5 years of tapping in individual plots—thinning from 125 to 110 trees per acre; 12.0% of stand	39.2	34.7	<0.10	1.8	5.2	6.9	<0.05	0.5
Checks in the middle of the ninth year of tapping in the experiment	40.2	35.2	<0.01	1.2	—	—	—	—

* Thinning was effected in a practical manner to retain a reasonably uniform stand while removing runts and low-yielding trees.

TABLE 5. TREE GIRTH MEASUREMENT DATA

Aspects*		Treatments							Main effects							Significance of interaction (P value)
		Low nitrogen		High nitrogen		Min. sig. diff.			Low N	High N	P	Nat.	Leg.	P	S.E.	
		Nat.	Leg.	Nat.	Leg.	0.05	0.01	0.001								
Mean girths for all trees in sampling cores (cm)	At 9/'57 measured at 60 inches	38.1	44.6	40.8	45.6	1.9	2.6	3.5	41.3	43.2	0.01	39.9	45.1	<0.001	0.5	0.20
	At 9/'59 measured at 72 inches	52.9	58.4	55.5	58.2	1.0	1.3	1.8	55.6	56.9	<0.05	54.2	58.3	<0.001	0.4	<0.05
	At 9/'67 measured at 72 inches	74.7	77.3	79.2	79.3	1.6	2.1	2.9	76.9	78.3	<0.05	76.0	79.2	<0.001	0.4	<0.05
Relative growth rates based upon common trees for periods	From 9/'59 to 9/'67	0.2552	0.2365	0.2513	0.2393	0.0132	0.0178	—	0.2458	0.2453	N.S.	0.2533	0.2379	<0.05	0.0022	N.S.
	From 9/'65 to 9/'67	0.0423	0.0395	0.0402	0.0410	0.0032	—	—	0.0409	0.0406	N.S.	0.0413	0.0402	N.S.	0.0008	N.S.

* 1. The first plots were opened up for tapping in September 1957.

2. All plots were in tapping as from September 1959—commencement of the third year of experimental tapping.
3. September 1967 marked the beginning of the eleventh year of tapping in the experiment.
4. Data relating to mean girths is not related to common trees and has not taken account of progressive thinning.
5. Relative growth rate is defined as the difference in the logarithms of cross-sectional areas of trunks at 72 inches as calculated from mean girths on common trees in sampling cores for the periods considered.

summarised in *Tables 6* and *7*. *Table 6* relates to all experimental plots irrespective of *M. cordata* weeding policy, while *Table 7* considers only leguminous cover plots and includes the influence of *M. cordata* weeding.

It will be seen from the *Tables* that measurements were taken both in relation to age of renewal and panel position. This was because differing times of commencing tapping in individual plots result in given ages of renewal occupying differing panel positions and this could have influenced findings. Examination of *Tables 6* and *7* shows, however, that this was not the case.

Root Counts and Distribution of Roots in Profiles

Neither foliage density nor nutrient status of leaf nor girth measurement considerations can be used to explain the yield advantage from having had a leguminous cover *(Table 1)* or the bark renewal findings *(Tables 6* and *7)*. For this reason root development of trees was examined. The work took place during the tenth year of tapping in the experiment and findings are summarised in *Figure 3*. Data in the figure were obtained by examination of 1782 profiles eight inches wide, fifteen inches deep and dug in the centres of avenues between the rubber tree planting rows. The roots counted were those from which latex oozed; grass and other roots were thus excluded from the count. At the sites of profiles there were 37% more rubber roots where previously there had been a leguminous rather than a natural ground cover. The influence of previous nitrogen policy was insignificant. No interaction was established between treatments.

Soil Analysis

Soil cores were taken from ten locations in the centres of interrows in the middle of plots for the purpose of estimating organic carbon, total nitrogen and the C/N relationship according to previous treatments. Sampling occurred during the eleventh year after tapping commenced within the experiment. No statistically significant differences were found to indicate differential residual effects of previous treatments. Summarised findings, irrespective of previous treatments, are presented in *Table 8*.

State of Ground Covers in the Middle of the Tenth Year of Tapping in the Experiment

This was the first check since the commencement of tapping. Plots were divided into six interrow avenues and the avenues into seventeen rectangles (spaces between four original planting points). Each square was given a score of 0 or 1 according to marked sparsity or moderate presence of ground covers. Findings are summarised in *Table 9*. Covers are more suppressed when tree rooting is best, *i.e.*, in the leguminous cover plots.

The competition by ground covers will have influenced the quantity of rubber roots but this influence is probably very small. Thus data in *Figure 3* are considered to be mainly a reflection of the previous effect of covers on soil quality.

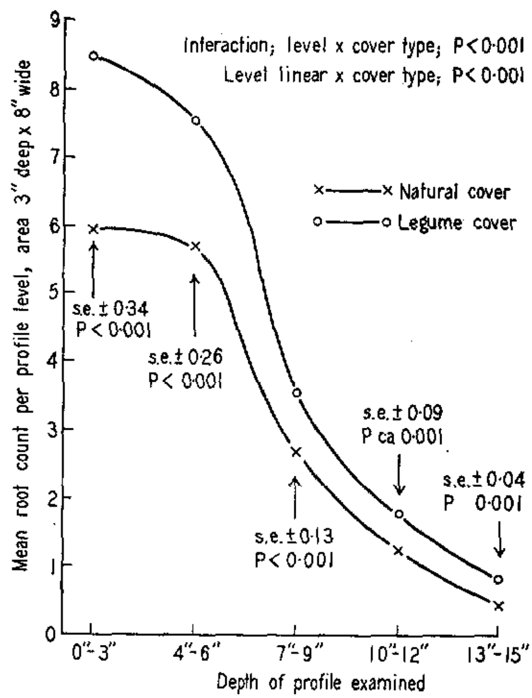

Figure 3. Numbers of cut rubber roots according to previous covers at nine years after commencement of tapping.

TABLE 6. BARK RENEWAL MEASUREMENTS* OBTAINED DURING THE TENTH YEAR OF TAPPING IN THE EXPERIMENT

Aspect	Panel	Treatments						Main effects							Significance of interaction
		Low N		High N		S.E.	P	Low N	High N	P	Nat.	Leg.	P	S.E.	
		Nat.	Leg.	Nat.	Leg.										
Age of renewal; 6 months	B	4.82	5.07	4.93	5.28	0.08	<0.01	4.95	5.11	0.05	4.88	5.18	0.001	0.05	N.S.
,, ,, ,, 12 ,,	B	5.29	5.64	5.32	5.62	0.07	<0.001	5.46	5.47	N.S.	5.30	5.63	<0.001	0.05	N.S.
,, ,, ,, 18 ,,	B	5.48	5.97	5.50	5.90	0.05	<0.001	5.72	5.70	N.S.	5.49	5.94	<0.001	0.04	N.S.
,, ,, ,, 66 ,,	A	7.25	8.00	7.46	8.01	0.09	<0.001	7.63	7.73	N.S.	7.35	8.01	<0.001	0.06	N.S.
,, ,, ,, 72 ,,	A	7.34	8.08	7.66	8.00	0.08	<0.001	7.71	7.83	<0.20	7.50	8.04	<0.001	0.06	<0.05
,, ,, ,, 78 ,,	A	7.40	8.13	7.67	8.08	0.09	<0.001	7.76	7.87	N.S.	7.53	8.10	<0.001	0.06	<0.10
20 inches from budding union	A	7.05	7.71	7.49	7.82	0.08	<0.001	7.38	7.65	<0.01	7.27	7.77	<0.001	0.06	<0.10
40 ,, ,, ,, ,,	A	7.23	7.81	7.60	7.85	0.10	<0.001	7.52	7.74	<0.05	7.41	7.84	<0.001	0.07	<0.20

* In millimetres

TABLE 7. BARK RENEWAL MEASUREMENTS* OBTAINED FROM EX-LEGUMINOUS COVER PLOTS DURING TENTH YEAR OF TAPPING IN THE EXPERIMENT

Aspect	Panel	*M. cordata* not weeded		*M. cordata* hand-weeded		Significance of interaction (P values)
		Low *nitrogen*	High *nitrogen*	Low *nitrogen*	High *nitrogen*	
Age of renewal; 6 months	B	5.09	5.27	5.05	5.29	N.S.
,, ,, ,, 12 ,,	B	5.61	5.69	5.67	5.54	N.S.
,, ,, ,, 18 ,,	B	6.00	5.96	5.94	5.85	N.S.
,, ,, ,, 66 ,,	A	7.90	8.13	8.11	7.89	<0.10
,, ,, ,, 72 ,,	A	7.91	8.16	8.24	7.84	<0.05
,, ,, ,, 78 ,,	A	7.99	8.28	8.27	7.88	<0.05
20 inches from budding union	A	7.69	7.95	7.73	7.69	N.S.
40 ,, ,, ,, ,,	A	7.73	8.16	7.89	7.59	<0.05

* In millimetres

TABLE 8. ORGANIC CARBON, TOTAL NITROGEN AND C/N IN RELATION TO OVEN-DRY SOIL PASSED THROUGH A 2 MM SIEVE

Horizon	Organic carbon (C), %	Total nitrogen (N), %	C/N
0 – 6″	0.85	0.083	10.3
6″ – 12″	0.59	0.060	9.8
12″ – 18″	0.50	0.052	9.7
S.E.	0.01	0.001	0.1
P	<0.001	<0.001	<0.01

TABLE 9. SCORED RELATIVE QUANTITIES OF GROUND COVERS IN TENTH YEAR OF EXPERIMENTAL TAPPING

Treatment	Ex-natural cover	Ex-leguminous cover	Mean N level
Low nitrogen	29.1	18.7	23.9
High nitrogen	25.7	14.7	20.2
	S.E. = 4.9 Interaction is N.S.		S.E. = 3.4 P is N.S.
Mean cover type	27.4	16.7	
	S.E. = 3.4 P = 0.05		

Cover species present during the check were:

Most common: *Axonopus compressus*
Panicum pilipes
Ficus fistulosa

Frequent : *Nephrolepis biserrata*
Centothecca lappacea

Occasional : *Pityrogramma calomelanos*
Mimosa pudica
Lygodium flexuosum
Panicum trigonium
Paspalum conjugatum
Centrosema pubescens

Pattern of Wintering and Associated Leaf Disease Incidence

In the tenth year of tapping the pattern of wintering was carefully followed. According to previous treatments, differences of importance and statistical significance were only established towards the end of the wintering period. In ex-leguminous cover plots the rate of hardening-off of new leaf was most rapid. During most of the study there was negligible leaf disease. The year was one favouring *Oidium hevea* to which the experimental clone, PB 86, is fairly resistant. *Gloeosporium alborubrum*, to which PB 86 is highly susceptible, did not appear until towards the end of refoliation. It was found to cause more secondary defoliation where leaf on trees was hardening off least rapidly.

The above findings are summarised in *Figure 4*. However it is appropriate to comment upon experimental technique. The pattern of wintering was checked by means of visual scoring, only one operator being involved. The bulk of leaf fallen due to infection by *Gloeosporium alborubrum* relates to hand collections. In each plot core, ten areas were bared of ground covers and from each of these, using a four-foot square quadrant, secondary leaf fall leaf was collected.

DISCUSSION AND CONCLUSIONS

The basic outstanding findings from this paper bear on the long-term effects of cover management and the application of increased quantities of nitrogen fertiliser during the immature period. A 20 per cent yield increase due to leguminous cover plants over the non-leguminous natural cover was recorded during the first ten years of tapping. The increase due to leguminous cover however showed a decline with time during the ten years of tapping. These give a strong support to soil improvement through cover management. Amelioration of rooting conditions was attained. The findings were as follows:

1. In relation to natural ground covers, legumes after seventeen years, allow better rooting. Apparently the condition for this improvement was assured by the time legumes had reached their

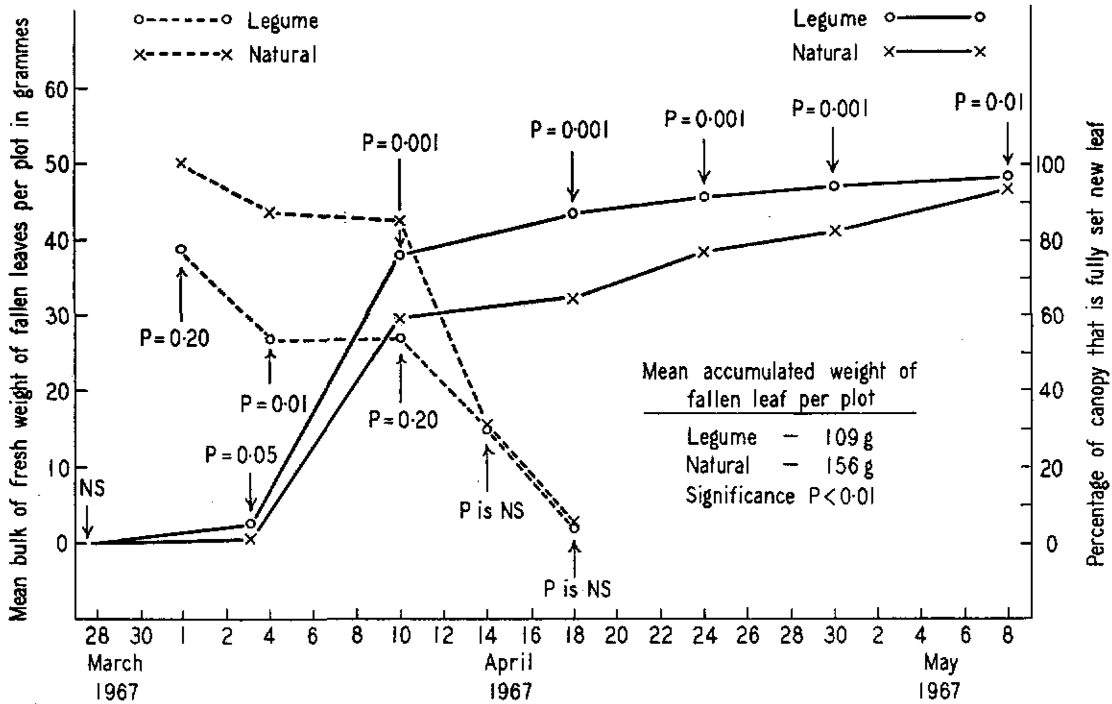

Figure 4. Secondary leaf fall and the pattern of hardening-off of leaf following wintering.

climax of development some three years after sowing. In support of this statement, influx of *M. cordata* into legume cover plots from this time onwards has not been shown to have affected quantity of rooting.

2. The level of nitrogen fertilisation applied prior to tapping, has not, as judged in the tenth year of tapping in the experiment, had any measurable differential effect on rooting of trees.

Excluding data in respect of *M. cordata* there is an apparent linkage between rooting and vigour of trees as judged by bark renewal. Further, due to more efficient rooting where legumes were grown, the possibility of more rapid hardening-off of young leaf, probably because of more rapid transpiration, results in a shorter period of susceptibility to leaf diseases. Disease incidence is therefore reduced.

Wong (1964) has already demonstrated that *M. cordata* can interfere with the uptake of nitrogen by other plants. The currently reported findings from legume plots appear complementary. They can probably be associated with conditions varying from deficiency to excess of nitrogen availability to trees. This, though not shown to have influenced rooting of trees, must have tended towards production of unbalanced growth, shortage or excess of leaf for instance. Only in this manner are bark renewal findings explicable *(Table 4)* and the regression of *Figure 2* for yield comprehensible. Regarding yield it must be remembered that when tapping on Panel B (opposite Panel A), the quality of renewal of Panel A is very important. Whether in the apparent case of excess nitrogen availability when legumes were weeded free of *M. cordata* and continuous nitrogen fertilisation occurred, supplementary application of other nutrients would have more than counter-balanced the observed ill effects, is open to speculation. Yields from the experimental area have already been excellent.

Whether they could have been improved upon to any appreciable extent is questionable.

One final point remains.

The residual effects of past treatments on trunk development now relate, not to relative growth rate in cross-sectional area, but to thickness of bark renewal. For mature trees in tapping it has been observed (MAINSTONE, 1963c) that fertilisation generally affects only girth increment. Thus on the poorer soils probably the magnitude of yield response of matured trees to fertilisers will depend upon its potential for bark renewal related to previous cover history during the pre-tapping period.

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DISCUSSION

Discussion on this paper is included in Gray (1969), see page 111.