*Effect of Cover Plants on Soil Nutrient Status and on Growth of Hevea III. A Comparison of Leguminous Creepers with Grasses and Mikania cordata**

G. A. WATSON, WONG PHUI WENG and R. NARAYANAN

In comparisons of the effects on the growth of Hevea *of leguminous creeping cover plants, mixed grasses* (Paspalum conjugatum *and* Axonopus compressus) *and* Mikania cordata, *the high nitrogen status of the legumes exercised a dominant influence. Compared with the non-legumes, leguminous creepers increased the rate of growth of immature* Hevea, *increased the level of soil nitrate-nitrogen and the* Hevea *leaf nitrogen content, and also increased the weight and nutrient content of* Hevea *leaf litter.*

In the cultivation of *Hevea*, cover plants, either natural or introduced, are grown in the inter-tree row areas as a soil conservation measure. In general, leguminous creepers are used for this purpose, but for many years there has been discussion regarding the value of such covers compared with naturally regenerating non-leguminous covers (WYCHERLEY, 1960; WATSON, 1957).

Experimental work in Malaya so far has shown that although leguminous creepers exert early competition with the tree (RUBBER RESEARCH INSTITUTE OF MALAYA, 1940) they may appreciably increase the rate of growth of the young tree and so shorten the period of immaturity (MAINSTONE, 1961). This beneficial effect has been confirmed by preliminary results from five field experiments laid down by the Rubber Research Institute of Malaya (WATSON, 1961; RUBBER RESEARCH INSTITUTE OF MALAYA, 1962) and this paper presents further data from the earliest and smallest of these experiments. More intensive studies have been carried out in this particular experiment than in the others, and it has been thought worthwhile to present the results in some detail. Results from the other experiments are consolidated in a further paper (WATSON *et al.*, 1964).

EXPERIMENTAL

The experiment is known as Experiment 23 and is sited on an infertile alluvial sandy soil of the Sungei Buloh series (OWEN, 1951) at the R.R.I.M. Experiment Station. Details of treatments and design are given in *Table 1*.

The particular cover plant treatments were chosen as being covers commonly found on estates and ones that have figured prominently in the cover plant controversy. The leguminous creepers (hereafter referred to as 'Legumes') were sown as a mixture of *Pueraria phaseoloides*, *Centrosema pubescens* and *Calopogonium mucunoides*. The grass cover was planted as turves and consisted of a mixture of *Axonopus compressus* and *Paspalum conjugatum*, predominantly the latter, while *Mikania cordata*, an ubiquitous creeper of the Compositae family, was established from cuttings.

Because of the very poor soil conditions, heavy fertiliser dressings (with manganese sulphate included at times) were required and details of these are given in a Supplement to this paper (WATSON *et al.*, 1963).

Tree heights and girths were recorded on the four rows, each originally of five trees, lying at the centre of each plot, while cover plant recordings were carried out in the five inter-row areas. The plot size in this experiment is about the minimum at which useful results might be expected and unfortunately heavy losses due to root disease and wind damage have introduced a large variability into the tree growth data. Despite this, useful results, similar to those found in the larger experiments but more detailed in some respects, have been obtained. Only

**Mikania cordata* has been commonly referred to in Malaya as *Mikania scandens* but a taxonomic study shows the former to be the correct name (see *Planters' Bulletin 71*, p. March 1964).

COMMUNICATION 361

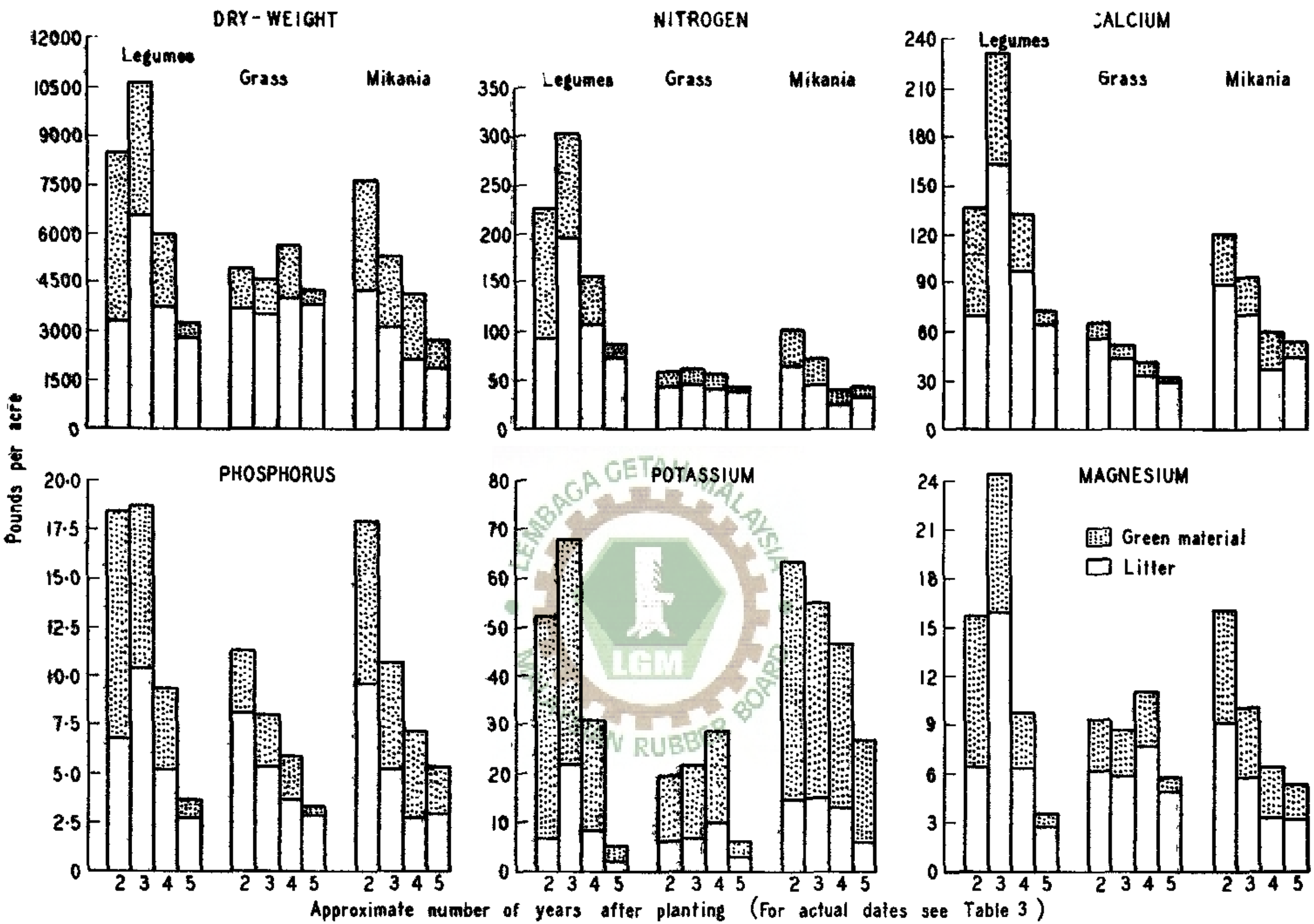

Figure 1. Changes in dry weight and nutrient content of covers with time (Results from 'fertiliser to rubber' treatment means only).

TABLE 1. EXPERIMENTAL DETAILS

Treatments		Replication and lay-out	Plot size and no. of trees per plot	Planting details
Cover plants	Method of application of fertilisers			
Leguminous creepers Grass *Mikania cordata*	Broadcast over tree rows (r), or cover (c)	Factorial treatments arranged randomly in 4 replicate blocks	0.3 acre 6 rows of 9 = 54 trees	Planted October, 1956 with Tjir 1 illegitimate stumps Budded January — March 1958 with RRIM 603

the more important data are presented in this paper, further details being given elsewhere (WATSON *et al.*, 1963; WATSON AND NARAYANAN 1963).

RESULTS

Cover Plant Data

Cover plant development in the experimental area followed the normal pattern, with vigorous growth over the first two years after planting and covers thereafter decreasing in vigour as the shade of the developing rubber trees increased. From the second year after planting the green material and litter of the covers were sampled annually for chemical analysis by harvesting 3 × 3 ft quadrats in the manner previously described (WATSON, 1961), but by the sixth year after planting the covers had declined so much in vigour that it was not possible to carry out a sampling because of the high variability. Accordingly in this year percentage soil cover was estimated using a point quadrat method, the results showing that *Mikania* was more vigorous than the other covers and that application of fertiliser to the covers had had little effect upon their vigour at this stage (WATSON *et al.*, 1963).

Percentage nutrient content. Determinations of the dry weight and percentage nutrient content of the green material and dead litter were made on all cover plant samplings. Full details of the individual samplings are given in the Supplement, but no major effects due to the method of fertiliser application were found and only data for the 'fertiliser to rubber' means are quoted in this paper. In addition differences in percentage nutrient content of the three covers were consistent at all samplings so that only data averaged over the four samplings need be discussed (*Table 2*).

The analytical results show that the leguminous creepers contained much higher levels of nitrogen and calcium and generally lower levels of potassium in the green materials and litter than did the other two covers. The *Mikania* cover contained comparatively high levels of phosphorus and potassium while the grass cover contained particularly low levels of calcium.

Dry matter production and total nutrient content. The total dry weight and nutrient content of the covers at each sampling have been calculated in terms of pounds per acre, and the data are shown in *Figure 1*. In the second, third and fourth years after planting, leguminous creepers produced greater total weights of dry matter and contained greater quantities of nitrogen, phosphorus and calcium than did either of the other covers, while *Mikania* consistently contained more phosphorus, potassium and calcium than did the grass, and contained more potassium than did the leguminous creepers in all years except the third.

The net changes taking place between successive annual samplings have been determined and are given in *Table 3*. Because of variability in the cover plant density at sampling, some of the differences fall short

TABLE 2. DRY WEIGHT AND PERCENTAGE NUTRIENT CONTENT OF COVER PLANT GREEN MATERIAL AND LITTER
(Data from 'fertiliser to rubber' treatment means only. Percentage nutrient content data meaned over the four samplings)

Material sampled		Green material					Litter				
Date of sampling	Treatment	Legumes	Grass	*Mikania*	s.e. of a cover mean (with l.s.d.)	Level of significance	Legumes	Grass	*Mikania*	s.e. of a cover mean (with l.s.d.)	Level of significance
Dry wt, lb per acre	26.6.58	5207	1182	3390	± 301.6 (909)	***	3342	3748	4287	±412.8 (1244)	
	19.8.59	4047	1054	2139	± 396.1 (1194)	***	6594	3545	3177	±400.4 (1207)	***
	23.9.60	2227	1649	1966	± 325.0 (979)		3772	4047	2198	± 556.2 (1676)	*
	5.9.61	536	389	883	± 187.1 (564)	(P< 0.10)	2753	3831	1899	±529.1 (1595)	*
% N		2.60	1.22	1.17	± 0.047 (0.14)	***	2.83	1.18	1.44	± 0.081 (0.24)	***
% P		0.197	0.202	0.262	± 0.0135 (0.041)	**	0.153	0.131	0.172	± 0.0137 (0.041)	(P<0.10)
% K		0.92	1.14	1.89	± 0.087 (0.26)	***	0.213	0.175	0.459	± 0.0185 (0.056)	***
% Ca		1.47	0.61	1.13	± 0.078 (0.24)	***	2.42	1.10	2.14	±0.101 (0.30)	***
% Mg		0.174	0.244	0.196	± 0.0139 (0.042)	***	0.176	0.164	0.190	±0.0129 (0.039)	
p.p.m. Mn		71	59	36	± 10.0 (30)	*	259	179	135	± 41.3 (124)	*

Level of significance obtained by testing the difference between the highest and lowest means by t-test (approx.).
*** = P<0.001, ** = P<0.01, * = P<0.05.

TABLE 3. CHANGES IN DRY WEIGHT AND NUTRIENT CONTENT OF COVER PLANTS (GREEN MATERIAL + LITTER) WITH TIME, IN LB PER ACRE

(Results from 'fertiliser to rubber' treatment means only)

Years after planting and date of sampling		At 2 26.6.58	2-3 Net change	At 3 19.8.59	3-4 Net change	At 4 23.9.60	4-5 Net change	At 5 5.9.61
Total dry weight	Legumes	8549	2092*††	10,641	–4642***	5999	–2710*	3289
	Grass	4930	– 331	4599	1096	5695	–1475	4220
	Mikania	7677	–2361*	5316	–1152	4164	–1382	2782
s.e. of any cover mean		±615.7		±686.2		±777.3		±657.5
(with l.s.d.)		(1856)		(2068)		(2343)		(1982)
Level of significance †		***		***				
s.e. of net change			±922.0		±1036.9		±1018.1	
N	Legumes	226.3	76.5	302.8	– 136.2	166.6	– 78.3	88.3
	Grass	60.8	3.0	63.8	– 6.1	57.7	– 13.9	43.8
	Mikania	102.0	28.1	73.9	– 32.2	41.7	2.8	44.5
P	Legumes	18.4	0.3	18.7	– 9.3	9.4	– 5.6	3.8
	Grass	11.3	– 3.2	8.1	– 2.1	6.0	2.7	3.3
	Mikania	17.9	– 7.2	10.7	– 3.5	7.2	– 1.8	5.4
K	Legumes	52.7	15.5	68.2	– 36.8	31.4	– 25.8	5.6
	Grass	20.1	2.2	22.3	6.7	29.0	– 22.8	6.2
	Mikania	63.8	– 8.1	55.7	– 8.6	47.1	– 19.9	27.2
Ca	Legumes	137.6	95.1	232.7	– 99.5	133.2	– 60.1	73.1
	Grass	66.7	– 14.6	52.1	– 9.5	42.6	– 10.1	32.5
	Mikania	120.8	– 52.2	95.6	– 35.5	60.1	– 4.2	55.9
Mg	Legumes	15.8	8.7	24.5	– 14.7	9.8	– 6.2	3.6
	Grass	9.4	– 0.7	8.7	2.3	11.0	– 5.0	6.0
	Mikania	16.6	– 6.5	10.1	– 3.6	6.5	– 1.1	5.4

† Level of significance obtained by testing the difference between the highest and lowest means by t test (approx.) with 15 d.f.

†† Level of significance obtained by testing the ratio of the net change to its s.e. by t test, with 30 d.f.

of statistical significance but the trends reflect the general order of effects taking place in the field. Grass covers showed some dieback in the third year after planting, but recovered slightly in the fourth year, while *Mikania* showed progressive decreases in vigour from the third year onward with net returns of nutrient to the soil. By the fourth and fifth year after planting a marked decrease in vigour coupled with a net return of nutrients to the soil by all covers took place, much higher levels of nitrogen, potassium, calcium and magnesium being returned from legumes than from the other covers. This was particularly so for nitrogen. Nitrogen return to the soil from 'Legume' covers between the third and fifth year after planting totalled 214.5 lb per acre, with 88.3 lb per acre nitrogen still held in the green material and litter of the standing cover at the end of the fifth year. Comparable figures for grass covers were 20.0 and 43.8 lb per acre, and for *Mikania* 29.4 and 44.5 lb per acre.

Surface Root Development of Hevea and Cover Plants

Observations in this and other experiments showed that vigorous development of surface roots by *Hevea* took place under the legume cover. Such development was evidently favoured by the heavy mulch of dead leaves that built up under this cover and the sheltered surface conditions.

A rather different condition was observed under the *Mikania cordata* : the *Mikania* did not deposit a heavy leaf mulch, the dead leaves withering and remaining attached to the stem, and the litter of this cover consisted largely of dead stems. The resulting conditions were rather more open than those under a cover of legumes, but while *Mikania* itself developed a vigorous mass of fine surface roots little rooting by *Hevea* was observed.

Only minor *Hevea* root development occurred under the grass covers, presumably because of the vigorous rooting of the grasses in the surface soil layers.

These visual observations were confirmed by data from a quadrat sampling of cover plant and *Hevea* roots above the surface and in the top three-inch soil layer (*Table 4*). From these data it can be seen that legume covers developed comparatively little rooting compared with that of grass and *Mikania*. Conversely, greater surface rooting by *Hevea* was shown under the legume covers than under either of the other two; it is interesting to note that in the legume treatments the application of fertiliser to the inter-row areas significantly depressed the amount of surface rooting by *Hevea*.

Soil Analytical Data

The experiment is sited on an infertile Sungei Buloh series alluvial coarse sandy soil which is very variable in nature because of the presence of patches of particularly coarse and humic sand. However, after a preliminary study of sampling methods, satisfactory soil samplings were carried out.

In 1960 twelve points per plot were sampled in the central three inter-row areas at depths of 0-6 in. and 12-18 in., the samples for each depth being bulked for analysis. A second, similar sampling was carried out for supplementary analysis in May, 1961. Data from these two samplings show the soil to be rather high in pH, total carbon, total nitrogen, available phosphorus, exchangeable calcium, but low in exchangeable magnesium and exchangeable potassium compared with normal inland soils (*Table 5*).

As would be expected the 0-6 in. layer of soil was found to contain higher levels of nutrients than the 12-18 in. layer but only few significant treatment effects were recorded. The exchangeable potassium content and pH value of 0-6 in. soil from under legumes were significantly lower than those under *Mikania* and there was a tendency for the exchangeable magnesium under legumes to be lower than that under grass and *Mikania*.

Where fertilisers were applied to covers, the phosphorus and exchangeable cation status of the 0-6 in. soil layer tended to be higher than where fertiliser was applied to the trees rows, but this effect was only significant for total and available phosphorus. There was a tendency in the legume treatments, for a similar effect on phosphorus to occur in the 12-18 in. soil layer, indicating that some downward movement of the applied phosphate may have occurred, perhaps by direct leaching through the soil,

TABLE 4. TREATMENT EFFECTS ON COVER PLANT AND RUBBER ROOT WEIGHTS (OZ PER SQ. YD)

Treatment		Legumes r	Legumes c	s.e. (with l.s.d.)	Grass r	Grass c	s.e. (with l.s.d.)	*Mikania* r	*Mikania* c	s.e. (with l.s.d.)
Cover plant roots	Above surface	3.45	0.98	±0.712 (2.46)	Nil	Nil	—	7.90	11.18	±2.253 (7.80)
	0 - 3 in.	5.98	6.26	±1.544 (5.34)	20.35	18.54	±1.378 (6.20)	13.70	18.19	±2.008 (6.95)
Rubber roots	Above surface	15.79	8.94	±2.914 (10.08)	1.71	1.91	±0.405 (1.29)	1.76	0.56	±0.405 (1.29)
	0 - 3 in.	39.7	25.6	± 3.77 (11.4)	21.0	17.9	± 3.77 (11.4)	16.0	16.8	± 3.77 (11.4)

TABLE 5. SOIL ANALYTICAL DATA

Date of sampling	Treatment		*Legumes* r	*Legumes* c	*Legumes* means	Grass r	Grass c	Grass means	*Mikania* r	*Mikania* c	*Mikania* means	Method means r	Method means c	s.e. (with l.s.d.) of a method mean for any depth	s.e. (with l.s.d.) of a cover mean for any depth	s.e. (with l.s.d.) of a depth mean for any cover
6.12.60	pH	0-6 in.	5.38	5.42	5.40	5.49	5.43	5.46	5.74	5.54	5.64	5.54	5.47	± 0.065	± 0.090	± 0.026
		12-18 in.	5.24	5.41	5.32	5.36	5.26	5.31	5.53	5.36	5.45	5.38	5.34	(0.20)	(0.24)	(0.10)
	% C	0-6 in.	2.10	2.44	2.27	2.60	2.44	2.52	2.58	2.32	2.45	2.43	2.40	± 0.123	± 0.150	± 0.086
		12-18 in.	1.04	1.26	1.15	1.38	1.21	1.30	1.37	1.18	1.27	1.26	1.21	(0.37)	(0.45)	(0.32)
	% total N	0-6 in.	0.160	0.175	0.167	0.182	0.167	0.175	0.178	0.164	0.171	0.173	0.169	± 0.0069	±0.0084	± 0.0066
		12-18 in.	0.069	0.085	0.077	0.090	0.081	0.086	0.094	0.079	0.086	0.084	0.082	(0.021)	(0.025)	(0.026)
	Total P, p.p.m.	0-6 in.	228	295	262	270	306	288	278	310	294	259	304	± 7.97	± 9.76	± 4.83
		12-18 in.	140	166	153	159	162	161	163	152	157	154	160	(24.0)	(29.4)	(14.8)
	Avail. P, p.p.m.	0-6 in.	20.5	34.8	27.7	29.6	37.5	33.5	23.7	39.4	31.6	24.6	37.2	± 1.43	± 1.75	± 1.45
		12-18 in.	11.5	15.7	13.6	11.8	14.2	13.0	10.7	14.1	12.4	11.4	14.7	(4.3)	(5.3)	(5.1)
11.5.61	Exch. Ca me/100g	0-6 in.	0.72	2.40	1.56	1.26	1.68	1.47	1.81	2.44	2.12	1.26	2.17	± 0.479	± 0.587	± 0.470
		12-18 in.	0.17	0.45	0.31	0.23	0.41	0.32	2.43	0.60	1.52	0.94	0.49	(1.44)	(1.77)	(1.53)
	Exch. Mg me/100g	0-6 in.	0.070	0.145	0.108	0.145	0.168	0.156	0.165	0.178	0.171	0.127	0.163	± 0.0143	±0.0175	± 0.0156
		12-18 in.	0.028	0.035	0.031	0.033	0.043	0.038	0.050	0.043	0.046	0.037	0.040	(0.043)	(0.053)	(0.048)
	Exch. K me/100g	0-6 in.	0.040	0.078	0.059	0.068	0.065	0.066	0.078	0.103	0.090	0.062	0.082	± 0.0067	± 0.0082	± 0.0073
		12-18 in.	0.020	0.028	0.024	0.025	0.030	0.028	0.040	0.038	0.039	0.028	0.032	(0.020)	(0.025)	(0.023)

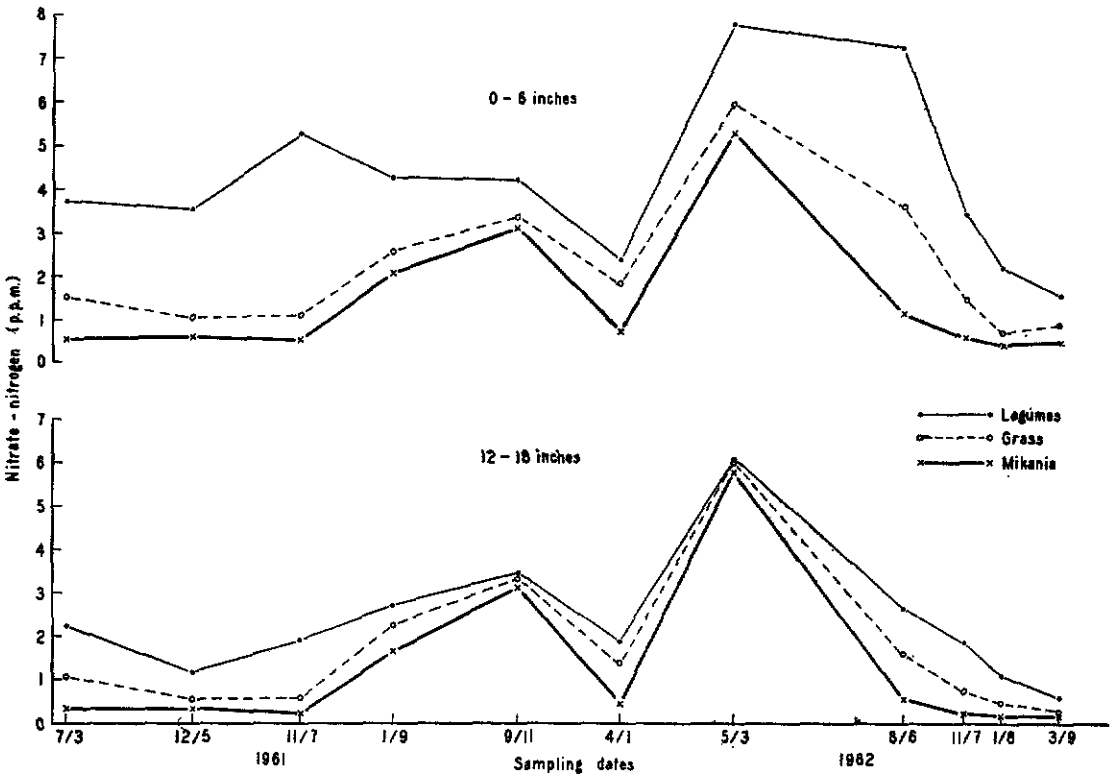

Figure 2. Variation in soil nitrate-nitrogen with time. In 0 - 6 in. samples, differences between highest and lowest values were significant at $P < 0.01$ or better on all sampling occasions. In 12 - 18 in. samples differences between highest and lowest values significant at $P < 0.05$ or better on all but two sampling occasions.

or by transport via the cover plants.

Soil nitrate-nitrogen. In preliminary soil studies it was found that treatment effects upon soil nitrate-nitrogen could be accurately determined by analysis of the bulked twelve samples per plot as used in the general sampling described above. Such samples were accordingly taken at intervals in 1961 and in 1962 at 0-6 in. and 12-18 in. depths.

Higher levels of nitrate-nitrogen were found under legume covers than under either of the other two at both depths and on all sampling occasions (*Figure 2*). At both depths, and on all occasions, the lowest levels of soil nitrate-nitrogen were found under *Mikania cordata;* such differences were not always statistically significant but the trend was quite consistent.

Levels of nitrate-nitrogen were higher in the 0-6 inches layer samples than those taken from 12-18 inches. There was a tendency for higher nitrate levels to be found in those plots where fertiliser was applied to the cover than in those where the fertiliser was applied to the rubber.

With some samplings the ammonium nitrogen content of the soil was determined. No significant treatment differences were found, but as the sampling intensity was not really adequate to make allowance for the variability of the soil ammonium content, no conclusions can be drawn, except perhaps

TABLE 6. TREATMENT EFFECTS ON HEVEA LEAF PERCENTAGE NUTRIENT CONTENT
(Meaned data over four annual samplings†)

Treatment	Legumes			Grass			*Mikania*			Method means		s.e. (with l.s.d.)		
	r	c	means	r	c	means	r	r	means	r	c	of a method mean	of a cover mean	of a cover × method mean
N	3.48	3.44	3.46	3.30	2.23	3.27	3.19	3.05	3.12	3.33	3.24	± 0.021 * (0.06)	± 0.026 *** (0.08)	± 0.037 (0.11)
P	0.225	0.223	0.224	0.219	0.222	0.221	0.207	0.213	0.210	0.217	0.219	± 0.0018 (0.005)	± 0.0022 *** (0.007)	± 0.0031 (0.009)
K	0.84	0.80	0.82	0.95	0.95	0.95	0.96	1.00	0.98	0.91	0.92	± 0.015 (0.05)	± 0.019 *** (0.06)	± 0.026 (0.08)
Ca	0.66	0.77	0.71	0.58	0.74	0.66	0.65	0.78	0.71	0.63	0.76	± 0.018 *** (0.05)	± 0.022 (0.07)	± 0.030 (0.09)
Mg	0.165	0.173	0.169	0.171	0.157	0.164	0.166	0.174	0.170	0.167	0.168	± 0.0027 (0.008)	± 0.0033 (0.010)	± 0.0047 (0.014) (P<.10)
Mn (p.p.m.)	72	46	59	57	34	45	55	36	46	61	39	± 2.4 *** (7)	± 3.0 ** (9)	± 4.2 (13)

† The four sampling dates were: (i) 28.10.59, (ii) 28.9.60, (iii) 4.9.61, (iv) 1.10.62.
*In the last 3 columns, levels of significance of F-test are shown as ***=P<0.001, **=P<0.01, *=P<0.05.

that if any treatment effects did occur they can only have been minor.

Hevea Leaf Nutrient Content

The leaves of the recorded trees in each plot were sampled annually over a period of four years. Chemical analysis showed the leaf content of magnesium and manganese to be consistently low, approximating to deficiency levels, despite the heavy fertiliser dressings.

Significant differences in leaf nutrient content were found between the four samplings, due probably to environmental effects and to variations in the age of the leaves at sampling, but the main treatment effects were consistent. Accordingly only data meaned over the different samplings are given (*Table 6*), detailed analytical figures being given in the Supplement.

Cover plant effects. The most important effects of cover plant treatment upon leaf nutrient content were that trees in the legume treatments contained appreciably higher nitrogen contents and lower potassium contents than did trees in either of the other treatments. Trees in the legume treatments were also found to show the highest leaf manganese contents. Trees in the *Mikania* treatments had significantly lower contents of nitrogen and phosphorus than did trees in either of the other two treatments. No significant differences were found in the leaf contents of calcium and magnesium.

Differences due to method of application of fertiliser. Significantly higher levels of leaf nitrogen and manganese, and lower levels of calcium, were found in those plots where fertiliser was applied to the trees in the planting row, than where fertiliser was applied broadcast over the inter-row areas. No consistent effects upon phosphorus, potassium and magnesium levels were observed.

Treatment Effects on Hevea Leaf Fall

Collections were made at fortnightly intervals of *Hevea* leaf-litter falling in the different treatments over a period of twelve

TABLE 7. TREATMENT EFFECTS ON HEVEA LEAF LITTER FALL

(Leaf litter collected over period 13.10.61 — 17.10.62; data quoted as grams per tree)

Treatment	Legumes		Grass		*Mikania*	
	r	c	r	c	r	c
Dry weight	7245	6175	3608	2753	2921	2083
Cover means	6710		3181			2502
s.e. (with l.s.d.)		±293.0		(903)		
Method means		r 4591		c 3671		
s.e. (with l.s.d.)		± 239.3 (737)				
N	108.6	90.0	50.6	42.8	38.8	27.0
P	12.9	11.0	8.7	7.9	8.2	7.1
K	4.7	3.7	2.3	2.1	1.7	1.2
Ca	268.2	185.2	76.7	70.4	89.5	62.3
Mg	14.2	12.8	6.3	6.1	5.0	4.9
Mn	0.15	0.09	0.07	0.04	0.04	0.03

months. A collection tray made from one-inch mesh netting and extending over the whole inter-row width, with a rubber tree at each corner, was laid out in each of the three central inter-row areas of all plots of one of the experimental blocks. With two plots of each cover in the block, collections were thus made from six trays for each cover treatment. The trays were placed so that the corner trees, as assessed by girth measurement and appearance, were as nearly as possible typical of the treatment, and the litter collected can be regarded as representing the litter fall from one tree (i.e. from four 'quarter' trees).

Analytical data on the collected litter confirmed treatment effects on the percentage nutrient content of fresh leaves (see Supplement), while data on the dry weight of the litter and its total nutrient content in grams per tree (*Table 7*) closely reflected the treatment effects on tree growth. The dry weight and total nutrient content of litter falling in the legume plots were approximately twice those in the grass plots, in which there was a significantly greater fall of litter than in the *Mikania* plots. Slightly higher figures were recorded in those plots where fertiliser was added to the tree rows than in those where fertiliser was applied to the covers.

As the falling leaf petioles passed through the mesh it was not possible to collect them together with the dead leaf laminae, and no data are available on the relative proportions of dead branch wood falling during the year; the weight of such material would in all probability reflect treatment differences similar to those found in the litter data.

Treatment Effects on Tree Growth

Height measurements of the unbudded seedlings at twelve months after planting, and of the young buddings at two years after planting (nine months after budding) showed no significant treatment effects. At the first recording, however, trees in the legume plots were slightly smaller than those in the other two cover plant treatments while in the second recording the position was reversed (*Table 8*).

To measure treatment effects on tree girth the growth history of those trees still present in December 1962 has been statistically

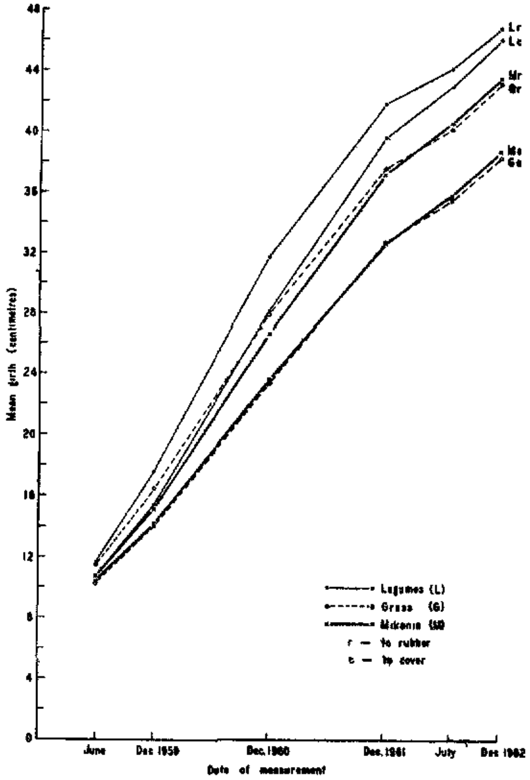

Figure 3. Treatment effects on rate of tree growth.

analysed and the data are given in *Table 8* and *Figure 3*. At seventeen months after budding, trees in the legume plots showed non-significantly larger girths than did trees in the other two cover plant treatments, and over the succeeding two and a half years the greatest rates of girth increment were shown by trees in the legume plots. In the initial stages trees in the grass plots were rather bigger than those in the *Mikania* plots but this position was reversed after two years from budding.

In legume plots, growth rates were initially better where fertiliser was applied directly to the rubber than where fertiliser was applied to the covers. However after about three years from budding this position was reversed so that in December, 1962 only

TABLE 8. TREATMENT EFFECTS ON TREE HEIGHTS, GIRTHS AND GIRTH INCREMENTS. JUNE 1959 — DECEMBER 1962

(Girth measurements for December, 1962 were made at 60 in. from the union; all others were recorded at 50 in.)

Recording	Date	Treatment	r	c	Means	s.e. (with l.s.d.) of a cover mean	s.e. (with l.s.d.) of a method mean	s.e. (with l.s.d.) of a method × cover mean
Height in units of 3 in.	12/10/57	Legumes (L)	30.64	31.34	30.99	± 0.731 (2.20)	± 0.597 (1.80)	± 1.033 (3.11)
		Grass (G)	30.94	31.81	31.38			
		Mikania (M)	31.04	32.40	31.72			
		Means	30.87	31.85				
Height in units of 3 in.	22/10/58	L	29.44	29.22	29.33	± 1.047 (3.16)	± 0.855 (2.58)	± 1.481 (4.46)
		G	28.23	28.12	28.17			
		M	29.05	28.01	28.53			
		means	28.90	28.45				
Girths in cm	6/59 (17 months after budding)	L	11.62	10.69	11.16	± 0.232 (0.70)	± 0.189 (0.57)	± 0.328 (0.99)
		G	11.43	10.22	10.83			
		M	10.71	10.42	10.57			
		means	11.25	10.44				
Overall girth increments in cm	6/59 to 7/62	L	32.56	32.36	32.46	± 0.458 (1.38) ***	±0.374 (1.13) ***	± 0.647 (1.95) *
		G	28.76	25.23	27.00			
		M	29.76	25.40	27.58			
		means	30.36	27.66				
Girths in cm	12/62 (59 months after budding)	L	46.87	46.11	46.49	± 0.590 (1.78) ***	± 0.481 (1.45) ***	± 0.834 (2.51) *
		G	43.15	38.33	40.74			
		M	43.51	38.71	41.11			
		means	44.51	41.05				

In the last 3 columns, levels of significance of F-test are shown as *** = $P<0.001$, * = $P<0.05$.

a non-significant difference in tree girth due to the method of fertiliser application was apparent. In the grass and *Mikania* plots differences due to the method of fertiliser application were more marked and although the effect diminished as the covers died away in 1962, final girth data showed that trees in the plots where fertiliser was applied directly to the rubber were significantly larger than those where fertiliser was applied to the covers.

In December 1962, tree girths in the legume plots were appreciably greater than those of trees in either grass or *Mikania* plots. It seems certain that the former trees will be the first to reach tappable size (50 cm approximately) and if the growth curves in *Figure 3* are extrapolated it appears that all the legume plots will be of tappable size some five months in advance of those grass and *Mikania* plots where fertiliser has been applied directly to the rubber, and some thirteen months in advance of those grass and *Mikania* plots where fertiliser has been applied to the covers.

DISCUSSION

The experiment has confirmed previous work in showing that under certain conditions young *Hevea* may grow faster when grown in association with leguminous creeping cover plants than with non-legumes. Of perhaps more interest in this particular experiment is its demonstration of the important influence of the high nitrogen content of the leguminous creepers.

Annual sampling of the three plant covers showed that the poorer growth of *Hevea* in the non-legume treatments was not due to any direct nutrient competition, for total nutrient contents of the grass and *Mikania cordata* covers were generally lower than those of the leguminous creepers. Severe competition for soil moisture by the non-legumes is also an unlikely explanation of the treatment effects since their production of dry matter was lower than that of the legumes, and since no consistent differences in soil moisture between the three cover plant treatments could be detected by soil analysis.

At all recordings except the first, trees in the legume treatments showed better growth than those in the grass and *Mikania* treatments, and it seems certain that this has been due to extra uptake of nutrients from the litter and soil under the leguminous creepers. The cover plant sampling data show that the leguminous creepers were outstandingly different from both the other covers in having a much higher percentage and total nitrogen content. Even before the covers began to die back in the fourth year after planting, this high nitrogen content of the legumes would exert a favourable effect on tree growth, for the dead litter of the leguminous creepers has a C/N ratio of approximately 15, while that of *Mikania cordata* is between 20 and 25 and that of grass approaches 40 (Watson, 1961). Nutrients in the litter of the leguminous creepers were therefore likely to be more easily available for uptake by the rubber or the cover plants than were nutrients in the litter of the non-legumes, with direct effects on the tree nutrient content (Guha and Watson, 1957). This is confirmed by the fact that in all samplings trees in the legume plots exhibited higher leaf nitrogen contents than did those in the non-legume plots, as well as by the greater total nutrient content of leaf litter fall in the legume plots.

The data in *Table 3* show that a massive return of nitrogen from the leguminous creepers to the soil occurred from the fourth year after planting onwards. The return was nearly 200 lb per acre in excess of that returned by the non-legumes, but since possible losses of nitrogen to the atmosphere and the release of nitrogen by the dying roots of the covers are not accounted for, this figure should be regarded only as an approximation of the true return. It can be compared with the 0.8 lb per tree (or approximately 120 lb per acre) of nitrogen applied in the fertiliser schedule quoted in the Supplement over the years 1956-1962. The effect on tree growth of this nutrient return is clearly seen when considering the differences in tree growth due to the method of applying fertilisers.

The two methods of applying fertiliser were introduced at eighteen months after planting (28.10.58) and measurements at eight and fourteen months later showed tree growth to be poorer in the 'fertiliser to cover' plots than where fertiliser was applied directly to the rubber. This was particularly so in the legume treatments where cover plant growth was then at its peak. In subsequent measurements this pattern altered, and over the period December 1960 to December 1961 the rate of tree growth in those legume plots where fertiliser was applied to the cover was actually better than where fertiliser was applied to the rubber, although the reverse still held true for the grass and *Mikania* treatments. This alteration followed the marked net return of nutrients to the soil by the leguminous creepers during 1960 and 1961, while at the same time measurements showed the rubber to be rooting much more strongly in the dead litter and surface soil under the legumes than under the grass and *Mikania* covers.

When the final girth measurements were taken in December 1962, little difference due to the method of fertiliser application was apparent in the legume treatments. In the grass and *Mikania* treatments, however, where nutrient release from the covers was much less, application of fertiliser to the inter-row areas, instead of to the rubber, only accentuated the difference between these and the legume treatments.

The fact that leaf litter fall in the legume plots was more than twice that in the non-legume plots confirms a positive effect of legumes on tree canopy density previously demonstrated indirectly by light penetration measurements (MAINSTONE, 1961) and suggests that the leguminous creepers produced larger effects on overall tree size than the tree girth data would indicate. The introduction of the associated organic matter and nutrients into the nutrient cycle will beneficially affect the vigour and productivity of the plantation long after the leguminous covers have died out.

Soil variability was such that no treatment effects on soil total and ammonium nitrogen could be detected, but soil nitrate-nitrogen levels were shown to be consistently higher under the leguminous creepers than under the grass or *Mikania* covers. Nitrate-nitrogen levels in the soil under *Mikania cordata* were slightly, but consistently, lower than those under the grass covers, and this may be linked with the lower levels of *Hevea* leaf nitrogen observed in the *Mikania* treatments. At the same time the C/N rates of the *Mikania* litter would be appreciably lower than that of grass litter so that the argument quoted above in the case of leguminous creepers does not apply, and this matter is the subject of current investigation.

It is of interest to note the decrease in exchangeable potassium content of the soil under leguminous covers, and the decreased content of potassium in the leaves of trees in the legume plots as compared with those in the non-legume plots. This effect seems linked with the high nitrogen status of the soil and tree in the legume treatments but it is difficult to say whether the effect is due to leaching of potassium together with nitrate from the soil, to some interaction at the root/soil exchange zone, or even in some degree to a direct dilution effect. BOLLE-JONES (1955) found a similar depressive effect of high levels of ammonium and nitrate nitrogen on *Hevea* leaf potassium content, in sand culture work.

The effect that leguminous creeping covers may have on tree growth has obvious economic implications, but since Experiment 23 is only small and sited on a soil type of restricted extent, this subject is left for discussion in a further paper which describes a number of more comprehensive experiments (WATSON *et al.*, 1964). The data presented above suggest however that the benefit of a leguminous cover is due largely to its high nutrient content, and particularly that of nitrogen, and that it would be of interest to determine whether the poorer rate of tree growth in the presence of non-luguminous covers could be compensated for by an increase in fertiliser application to the rubber.

ACKNOWLEDGEMENTS

The authors acknowledge with gratitude the assistance of Mr D. R. Westgarth in the statistical assessment of data, and of Mr K.

Ratnasingam who supervised all the chemical analysis. Thanks are also due to Mr R. F. Harley, Manager of the R.R.I.M. Experiment Station, and to Mr A. V. S. Nathan and other field assistants for their assistance in maintenance and sampling of the experiment.

Soils Division
Rubber Research Institute of Malaya
Kuala Lumpur *May 1963*

REFERENCES

BOLLE-JONES, E. W. (1955) Comparative effects of ammonium and nitrate ions on the growth and composition of *Hevea brasiliensis. Physiol. Plant* **8**, 606.

GUHA, M. M. AND WATSON, G. A. Effects of cover plants on soil nutrient status and on growth of *Hevea* I. Laboratory studies on the mineralisation of nitrogen in different soil mixtures *J. Rubb. Res. Inst. Malaya* **15**, 175.

MAINSTONE, B. J. (1961) Effects of ground-cover type and continuity of nitrogenous fertiliser treatment upon the growth to tappable maturity of *Hevea brasiliensis. Proc. Nat. Rubb. Res. Conf., Kuala Lumpur, 1960*, 362.

OWEN, G. (1951) A provisional classification of Malayan soils. *J. Rubb. Res. Inst. Malaya* **13**, 20.

RUBBER RESEARCH INSTITUTE OF MALAYA (1940) *Rep. Rubb. Res. Inst. Malaya 1939*, 72.

RUBBER RESEARCH INSTITUTE OF MALAYA (1962) *Rep. Rubb. Res. Inst. Malaya 1961*, 25.

WATSON, G. A. (1957) Cover plants in rubber cultivation *J. Rubb. Res. Inst. Malaya* **15**, 2.

WATSON, G. A. (1961) Cover plants and the soil nutrient cycle in *Hevea* cultivation. *Proc. Nat. Rubb. Res. Conf., Kuala Lumpur, 1960*, 352.

WATSON, G. A. AND NARAYANAN, R. (1963) Statistical study for poaching effects in cover plant experiments. *Research Archives of the R.R.I.M.* Document No. 23.

WATSON, G. A., WONG, P. W. AND NARAYANAN, R. (1963) A supplement to the paper: Effect of cover plants on soil nutrient status and on growth of *Hevea* III. A comparison of leguminous creepers with grasses and *Mikania cordata. Rubb. Res. Inst. Malaya, Archives Document* No. 21.

WATSON, G. A., WONG, P. W. AND NARAYANAN, R. (1964). Effect of cover plants on soil nutrient status and on growth of *Hevea* IV. Comparisons of leguminous creepers, with grasses, *Mikania cordata* and mixed indigenous covers on four soil types. *J. Rubb Res. Inst. Malaya* **18** (in the press).

WYCHERLEY, P. R. (1960) Vegetation of rubber plantations. *J. Rubb. Res. Inst. Malaya* **16**. 87.