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STUDIES ON THE NUTRIENT STATUS OF SOME COCONUT SOILS IN CEYLON

8. THE LATERITIC GRAVEL AT GONAPINUWELA

By

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SUMMARY

Six pot experiments were carried out to assess the nutrient status of the lateritic gravel at Gonapinuwela. The soil was found to be deficient in nitrogen, phosphorus, potassium, magnesium and boron.

In the absence of added nitrogenous fertilizers the relative yield dropped to nearly 20% of the treatment with the complete fertilizer. Among the forms of nitrogenous fertilizers tested, effectiveness decreased as the ability to decrease the pH of the soil increased.

Phosphorus gave very big response at the early stages (relative yield below 5%) but the effectiveness decreased with time (relative yield of 55% at the final harvest). Maximum yield was obtained with the application of 4 cwt. $NaH_2PO_4 \cdot 2H_2O$ per acre.

Potassium was without effect at the early stages but relative yields dropped almost linearly with time and at the final harvest there was little or no growth in pots that did not receive potassium. Maximum yields were obtained with the application of 4 cwt K_2SO_4 per acre.

Calcium was generally without effect, except in the case of plants requiring a high soil pH.

Magnesium had varying effects, entering into negative interaction with phosphorus and potassium. As the level of these nutrients increased there was a progressive reduction in the response to the levels of magnesium, which at the highest levels of phosphorus and potassium led to a progressive depression. Maximum yields were obtained at 1 cwt $MgSO_4 \cdot 7H_2O$ per acre.

Boron was found to be necessary for satisfactory growth of legumes and maximum yields were obtained with the application of 3 lb $Na_2B_4O_7 \cdot 10H_2O$ per acre.

The soil was found to have satisfactory levels of all other nutrients.

INTRODUCTION

Gonapinuwela is situated about 10 miles East of Hikkaduwa in the Southern Province. The area is typical of the Low Country Wet Zone, receiving 125 inches rainfall annually with practically no dry periods. The land is undulating. The area has been recently surveyed by Perera (1965) who distinguishes two soil types, namely: the "Baddegama series" where the surface soil is a coarse sandy clay loam with fine gravel particles of lateritic origin on the elevations and slopes, and the "Hikkaduwa series" characterised by loamy sand along the basins of the minor streams (*Fig. 1*). The latter series is of minor importance from the point of view of coconut cultivation. The two series may be termed and compared to the "lateritic gravel" and "lateritic sand" respectively described by Paltridge and Santhirasegaram (1957) from Bandirippuwa. The absence of the "lateritic loam" may be due to the greater inclination of these slopes and higher rainfall and consequent wash at Gonapinuwela compared to Bandirippuwa. It is interesting to note that as one examines the soil catenary formation from North to South in the Western sector of the island, the slope of the catena, the extent of gravel and the rainfall increases. There is also a progressive reduction in the loam and sand sections, both in relative and absolute terms. Further details of these physical features and their relationship to nutrient status will be dealt with elsewhere.

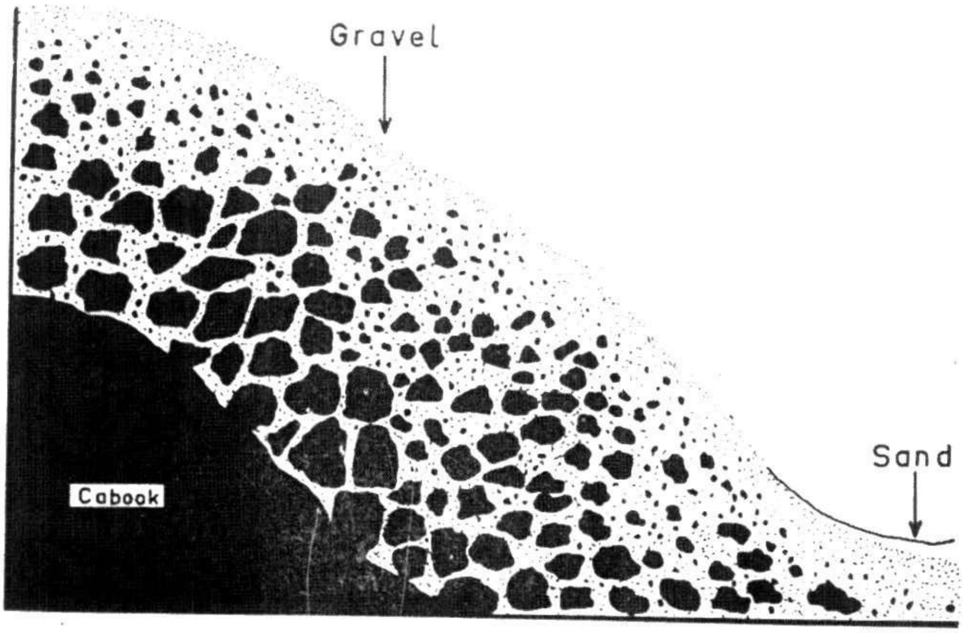

FIGURE 1—Diagram of the profile of the catena at Gonapinuwela.

The nutrient status of the Gonapinuwela gravel is of particular interest in view of the prevalence of the "leaf scorch" condition of the coconut palms in the area. The unusual symptoms observed with *Medicago sativa* planted in this soil soon after sampling, have been described by Santhirasegaram and Ekanayake (1964). They showed that the cause could not be due to any deficiency or toxicity of known plant nutrients, and that it was due to some soil borne organisms or substances, and suggested that it was probably due to a nematode *Hemicycliophora langicaudata* (Loos). In a more recent study Robertson (personal communication) concluded that this nematode is unlikely to cause the "leaf scorch" condition of coconut palms. There had been some claims (Warasawithana, personal communication) that affected palms have been cured by the application of mercury based fungicides, but Keerthisinghe, (personal communication) has not been able to confirm this as yet. However search for pathogenic organisms by Abeygunawardena (personal communication) had been unsuccessful. Nethsinghe (personal communication) has not been able to detect any relationship between the condition of the palms and plant nutrients.

This paper deals with the nutrient status of the Gonapinuwela gravel, studied in pots using indicator plants.

EXPERIMENTAL

The experimental techniques were the same as described by Paltridge and Santhirasegaram (1957). Essentially, the soil sample for the experiments was collected from the centre of a number of coconut squares upto a depth of 9" and thoroughly mixed, air dried, and after seiving through a ¼" mesh were filled in 6" polysterene flower pots. Each pot represented a "plot". Responses were measured in terms of plant dry matter produced above soil surface. The test plants were *Paspalum commersonii* (Lam), *Phaseolus lathyroides* (L), *Medicago sativa* (L) and *Sesamum indicum* (L).

All chemicals used were of A.R. grade and the pots were brought to 85% field capacity by weight daily with water passed through resin columns and then distilled in pyrex ware. The experiments were conducted in the Institute's " Phytosolaria ".

a. Experiment to assess the status of major nutrients (N, P, K, Ca and Mg)

This was a 2^5 factorial of two levels of the five nutrients with two replicates of all treatments planted to *P. commersonii* and one replicate planted to each of *P. lathyroides* and *S. indicum.*

All nutrients were applied as solutions in forms and rates given in *Table I*, except calcium, which was applied as $CaCO_3$ powder and mixed with the top 1½" of soil. A basal application of the minor nutrients (Fe, Cu, Zn, Mn, Mo and B) were made at the time of planting.

TABLE I

Forms and rates of nutrients applied.

Designation	*Chemical*	*Rate of application/acre*
N	$(NH_4)_2SO_4$	5 cwt = 118 lb N + 135.7 lb S
P	$Na\,H_2PO_4.\ 2H_2O$	3 cwt = 66.8 lb P + 49.5 lb Na
K	K_2SO_4	3 cwt = 150.6 lb K + 61.8 lb S
Ca	$CaCO_3$	10 cwt = 448 lb Ca
Mg	$MgSO_4.\ 7H_2O$	1 cwt = 11.8 lb Mg + 14.5 lb S
Fe	$FeSO_4.\ 7H_2O$	7 lb = 1.4 lb Fe + 0.8 lb S
Cu	$CuSO_4.\ 5H_2O$	7 lb = 1.8 lb Cu + 0.9 lb S
Zn	$ZnSO_4.\ 7H_2O$	7 lb = 1.5 lb Zn + 0.8 lb S
Mn	$MnSO_4.\ 4H_2O$	7 lb = 1.75 lb Mn + 1.0 lb S
Mo	$(NH_4)_6Mo_7O_{24}.\ 4H_2O$	1 lb = 0.5 lb Mo + 0.07 lb N
B	$Na_2B_4O_7.\ 10H_2O$	3 lb = 0.13 lb B + 0.13 lb Na

P. commersonii was harvested on three occasions while the other two species were harvested only once. " Thinnings " at an early stage of growth was made with all species to obtain additional information. Nitrogen to the appropriate pots was applied prior to each harvest.

(b) Experiment to assess the status of minor nutrients (Cu, Zn, Mn and Mg)

This was a 2^4 factorial with two replicates of all treatments planted to *P. commersonii.* All other nutrients were applied as basal at the time of planting and those found effective in *Experiment a* were reapplied as and when considered necessary. The experiment was harvested on three occasions. The plants were removed at this stage and replanted with seeds again. Three further harvests were made with the second planting.

(c) Experiment to assess the status of minor nutrients (Fe, Cu, Mn, B and Mg)

This was a 2^5 factorial with two replicates of all treatments planted to *M. sativa.* All other nutrients were applied as basal at the time of planting and were reapplied during the course of the experiment as and when considered necessary. The experiment was harvested on two occasions.

(*d*) Experiment to assess the effect of three forms of nitrogen in presence and absence of sulphur and copper.

This was a 3×2^2 factorial of three forms of nitrogen (NH_4NO_3, $(NH_4)_2SO_4$ and $CO(NH_2)_2$) with equivalent amounts of N(118 lb/ac), two levels of sulphur (0 and 1 cwt. S/ac) and two levels of copper (0 and 7 lb $CuSO_4$. $5H_2O$/ac) planted to *P. commersonii*. Phosphorus (3 cwt/ac NaH_2PO_4. $2H_2O$), potassium (3 cwt/ac K_2SO_4), calcium (10 cwt/ac $CaCO_3$) and magnesium (1 cwt/ac $MgSO_4$. $7H_2O$) were applied as basal at time of planting. There were three replicates of all treatments. The experiment was harvested on three occasions and the forms of nitrogen were reapplied prior to each harvest.

(*e*) Experiment to determine optimum dosage of P, K and Mg.

This experiment was on a composite design (Davies 1956) with the three nutrients at five levels of each. Phosphorus was applied as NaH_2PO_4. $2H_2O$, at levels of 0, 1½, 3, 4½ and 6 cwts/ac. Potassium was applied as K_2SO_4 and at the same levels as for phosphorus. Magnesium was applied as $MgSO_4$. $7H_2O$, at levels of 0, ½, 1, 1½ and 2 cwt/ac. The experiment was planted to *P. commersonii* and *P. lathyroides*. The set of treatments for each species was replicated twice. The grass was harvested on three occasions and the legume twice. Nitrogen was applied (5 cwt/ac $(NH_4)_2SO_4$) as basal at time of planting and in the case of the grass it was reapplied prior to each harvest.

The data were statistically analysed according to Inkson (1966). The Appendix gives the treatments and form of analysis.

(*f*) Experiment to assess the optimum dosage of boron in presence and absence of calcium.

This was a 4 × 2 factorial of four levels of boron (0, 3, 6 and 12 lb $Na_2B_4O_7$. $10H_2O$/ac) and two levels of calcium (0 and 10 cwt $CaCO_3$/ac) planted to *M. sativa* with four replicates of all treatments. Nitrogen, phosphorus and potassium were applied as basal at the time of planting and repeated as required. The experiment was harvested on three occasions.

RESULTS

(*a*) Major nutrients (N, P, K, Ca and Mg).

In the case of *P. commersonii*, calcium and magnesium were without effect and in *Table 2*, the yield response of this species to nitrogen, phosphorus and potassium at the various harvests are presented.

TABLE 2

Mean dry matter yield (g/plant) of *P. commersonii* in presence of all combinations of N, P and K at successive harvests.

Treatment	H_1	H_2	H_3	*Total*
Nil	0.06	0.42	0.42	0.90
N	0.09	0.48	0.34	0.92
P	4.06	0.79	0.23	5.07
K	0.10	0.81	0.41	1.30
NP	5.64	1.69	0.08	7.40
NK	0.14	0.58	0.61	1.34
PK	4.61	0.64	0.31	5.55
NPK	8.19	3.59	1.08	12.73
L.s.d. 5%	0.36	0.14	0.14	0.40
1%	0.44	0.19	0.19	0.53
0.1%	0.61	0.25	0.25	0.70

When applied alone, only phosphorus had any substantial effect, and that too only up to the first harvest. When nitrogen and potassium were applied individually with phosphorus (NP and KP) there was a further increase in yield, but the combination of nitrogen and potassium (NK) was not effective. The combination of the three nutrients together gave the highest yields.

In *Fig. 2*, the pattern of response to the individual nutrients are presented as relative yields, where the yield in absence of a nutrient was calculated as percentage of the yield in presence of all effective nutrients (NPK). In the absence of nitrogen the relative yield was 79% at thinnings and it decreased steadily to 17% at the second harvest and thereafter remained almost constant. In absence of phosphorus the relative yields up to the first harvest were very low, indicating acute deficiency of the nutrient in the soil, but it rose to 16% at the second harvest and to 56% at the final harvest. The absence of potassium had no effect at thinnings with relative yield of 99%, but it dropped almost linearly with time to reach 8% at the final harvest.

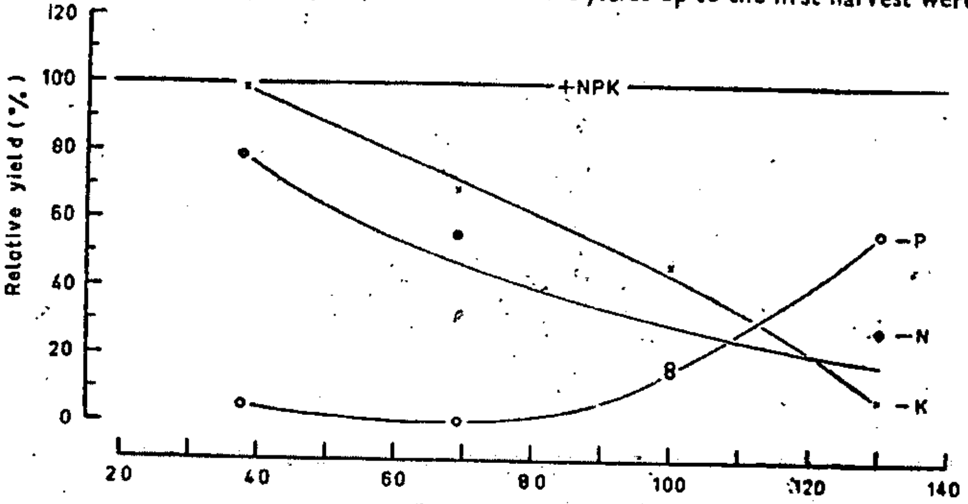

FIGURE 2—Relative yield of *P. commersonii* in absence of individual nutrients with time.

With *P. lathyroides* in addition to calcium and magnesium, there was no response to nitrogen (*Table 3*), which is to be expected as this species being a legume with effective nodulation.

TABLE 3

Mean dry matter yield (g/plant) of *P. lathyroides* and *S. indicum* in presence of all combinations of N, P and K.

Nutrients	*P. lathyroides*	*S. indicum*
Nil	0.01	0.02
N	0.04	0.01
P	1.00	0.44
K	0.09	0.02
NP	0.76	0.46
NK	0.28	0.01
PK	1.91	0.45
NPK	2.05	0.54
L.s.d. 5%	0.36	0.07
1%	0.50	0.11
0.1%	0.80	0.18

The response of *S. indicum* to phosphorus was as marked with the other species. At the only harvest made there was very little response to nitrogen and potassium (*Table 3*). An interesting feature with this species was the effect of calcium. This nutrient was responsible for increase in yields and entered into positive interactions with nitrogen, phosphorus and potassium (*Table 4*). Magnesium was without effect with this species also.

TABLE 4

Mean dry matter yield (g/plant) of *S. indicum* in presence and absence of Calcium of the first order combinations of N, P and K.

	Ca_0	Ca_{10}
NP	0.58	1.42
NK	0.43	0.67
PK	0.80	1.67
L.s.d. 5% = 0.07 ; 1% = 0.11; 0.1% = 0.18		

(*b*) Minor nutrients (Cu, Zn, Mn and Mg)

Over the entire duration of the first planting none of the nutrients had any positive effect. There were some minor first order interactions between copper, zinc and manganese, which however were inconsistent.

During the second planting however, magnesium had some beneficial effect which increased with time (*Table 5*).

TABLE 5

Mean dry matter yield of *P. commersonii* in presence and absence of magnesium at successive harvests of second planting.

	H_1	H_2	H_3
Mg_0	1.04	2.16	1.26
Mg_1	1.40	2.76	2.40
% increase	34.6	27.80	90.5
Level of Sig.	1%	1%	0.1%

(*c*) Minor nutrients (Fe, Cu, Mn, B and Mg)

Of the nutrients tested for, only boron had any effect. There was a 20% increase in yield at the first harvest (sig. at 5%.) but a 20% depression was observed at the next harvest (not sig.). The plants in this experiment developed symptoms which could not be attributed to any known effect of nutrient deficiencies or toxicities. It is to be noted that this experiment was the first to be laid soon after the soil was sampled. All others were set up after some length of storage of the soil sample. The symptoms observed and the possible implications have already been dealt with (Santhirasegaram and Ekanayake 1964).

The coefficient of variation in this experiment was 23.56 and 49.32% at the first and second harvests respectively. The variation normally encountered in these pot experiments is around 7%.

(*d*) Forms of nitrogen in presence and absence of sulphur and copper

Sulphur and copper had no effect on yields. There was no significant difference in the effect of forms of nitrogen at the first harvest, though $(NH_4)_2SO_4$ was less effective than the others. Later however, the depressive effect of $(NH_4)_2SO_4$ compared to NH_4NO_3 was marked, and it increased with time (*Table 6*). A similar, but less marked effect was observed with $CO(NH_2)_2$. Fig. 3 shows the effect of $(NH_4)_2SO_4$ and $CO(NH_2)_2$ relative to that of NH_4NO_3 with time.

TABLE 6

Mean dry matter yield of *P. commersonii* to three forms of nitrogen at successive harvests.

	H_1	H_2	H_3
NH_4NO_3	5.62	4.67	1.74
$CO(NH_2)_2$	5.71	4.13	1.14
$(NH_4)_2SO_4$	5.32	3.71	0.91
L.s.d. 5%	NS	0.50	0.45
1%	NS	0.68	0.61
0.1%	NS	0.92	0.82

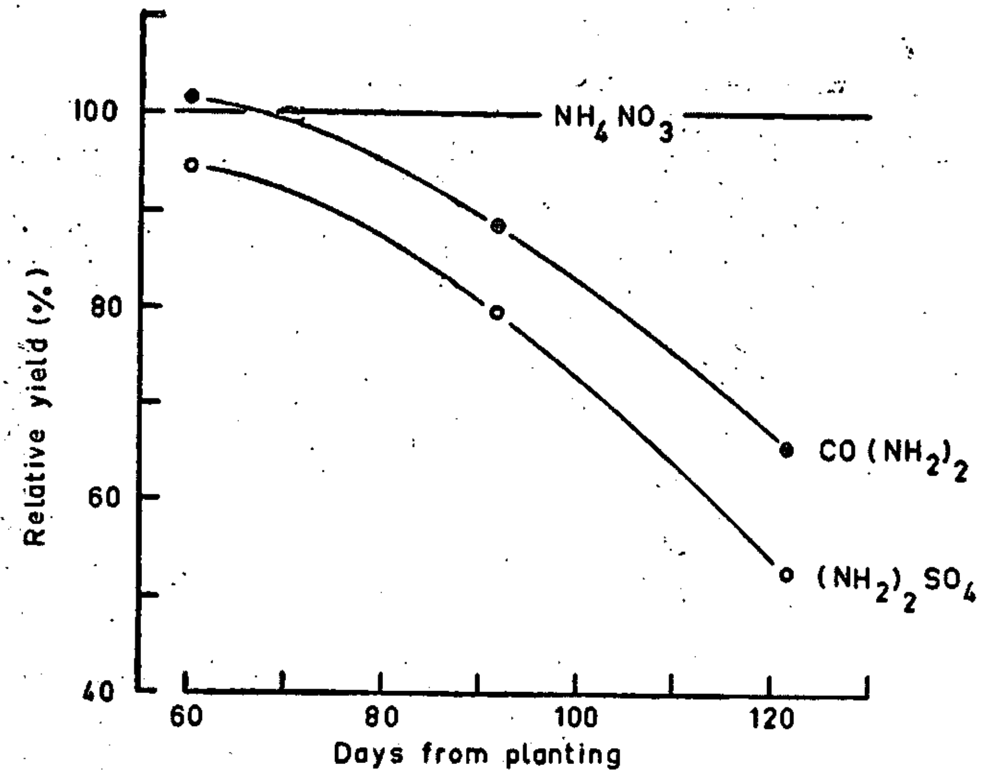

FIGURE 3—Yield of *P. commersonii* due to $(NH_4)_2SO_4$ and $CO(NH_2)_2$ relative to NH_4NO_3 with time.

(e) Optimum dosage of phosphorus, potassium and magnesium.

With *P. commersonii*, phosphorus and potassium had significant main effects at all harvests. (*Table* 7). Magnesium also had considerable main effects though not significant.

TABLE 7

Analysis of variance of dry matter yield of *P. commersonii* at third harvest.

Treatments		*b values*	*t*	*level of sig.* (%)
P	L	0.3713	2.71	1
	Q	—0.3742	3.62	0.1
K	L	0.5618	4.10	0.1
	Q	—0.3830	3.71	0.1
Mg	L	0.2632	1.92	
	Q	—0.1330	1.29	
PK		—0.0987	—	
PMg		—0.2417	1.83	
KMg		—0.2522	1.91	

The main effects of the three nutrients are shown in *Fig.* 4 for the three harvests.

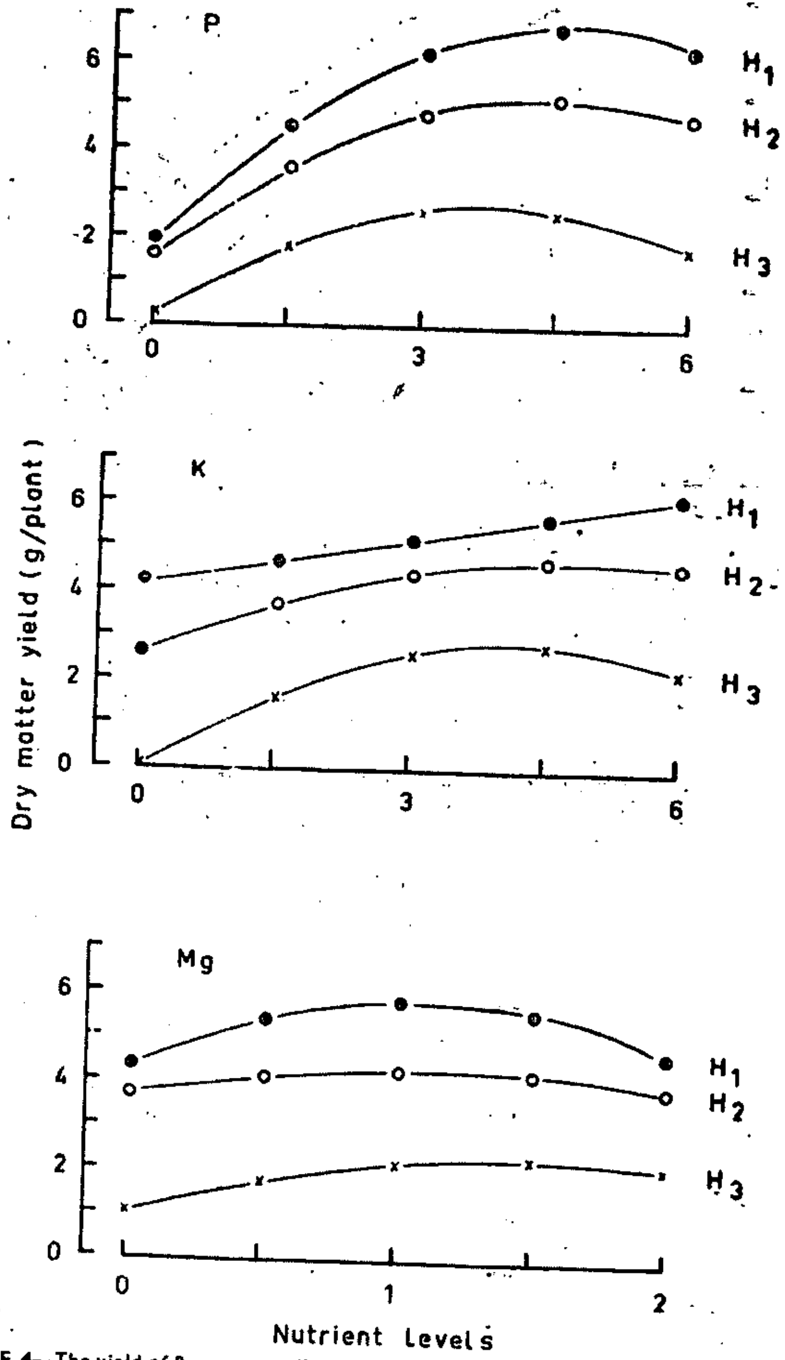

FIGURE 4—The yield of *P. commersonii* to various levels of P, K and Mg at successive harvests.

There was no interaction between phosphorus and potassium. Magnesium however entered into negative interaction with phosphorus and potassium, though not significant. In general with increase in the level of phosphorus or potassium, there was a decrease in the response to magnesium. These patterns were similar to that with *P. lathyroides*, where they were significant, and are presented in greater detail.

The yield functions in terms of the nutrients were as follows:—

Harvest 1. $y = 0.12 + 1.82P + 0.33K + 3.55Mg - 0.22P^2 + 0.01K^2 - 1.30Mg^2 + 0.08PK - 0.00\,PMg - 0.27\,KMg.$

Harvest 2. $y = -0.77 + 1.51\,P + 0.99\,K + 2.21\,Mg - 0.17\,P^2 - 0.09\,K^2 - 0.45\,Mg^2 + 0.04\,PK - 0.13\,PMg - 0.28\,KMg.$

Harvest 3. $y = -4.72 + 1.70\,P + 1.86\,K + 3.57\,Mg - 0.17\,P^2 - 0.17K^2 - 0.53\,Mg^2 - 0.04\,PK - 0.32\,PMg - 0.34\,KMg.$

Mean of Harvests $y = -1.73 + 1.66\,P + 1.06\,K + 3.11Mg - 0.19\,P^2 - 0.08\,K^2 - 0.76\,Mg^2 + 0.03\,PK - 0.15\,PMg - 0.30\,KMg.$

The optimum combination of nutrients that gave the maximum yield at the third harvest was:—

Phosphorus	3.63 cwt $NaH_2PO_4.\ 2H_2O$/ac.
Potassium	4.05 cwt K_2SO_4/ac.
Magnesium	0.97 cwt $MgSO_4.\ 7H_2O$/ac.

With *P. lathyroides*, phosphorus was responsible for a linear response at the first harvest, but at the second it was curvilinear. Potassium and magnesium had no significant main effects. *Table 8* gives a summary of statistical analysis of the second harvest and *Fig 5.* the main effects of the three nutrients at the two harvests. Magnesium entered into negative interactions with both phosphorus and potassium as in the case of the grass. In the absence of phosphorus there was an almost linear response to the levels of magnesium. With increase in the levels of phosphorus the response to the levels of magnesium decreased and at $P_{4\frac{1}{2}}$ there was little or no response to the various levels of magnesium. At the highest level of phosphorus (P_6) there was a progressive depression to the various levels of magnesium (*Fig. 6*). The reverse effect of levels

TABLE 8

Analysis of variance of dry matter yield of *P. lathyroides* at the second harvest.

Treatments		*b values*	*t*	*level of sig.* (%)
P	L	0.1669	5.23	0.1
	Q	—0.1357	5.63	0.1
K	L	—0.0568	1.78	
	Q	—0.0113	—	
Mg	L	0.0595	1.86	
	Q	—0.0201	—	
PK		—0.0180	—	
PMg		—0.0730	3.23	1.0
KMg		—0.0863	3.82	0.1

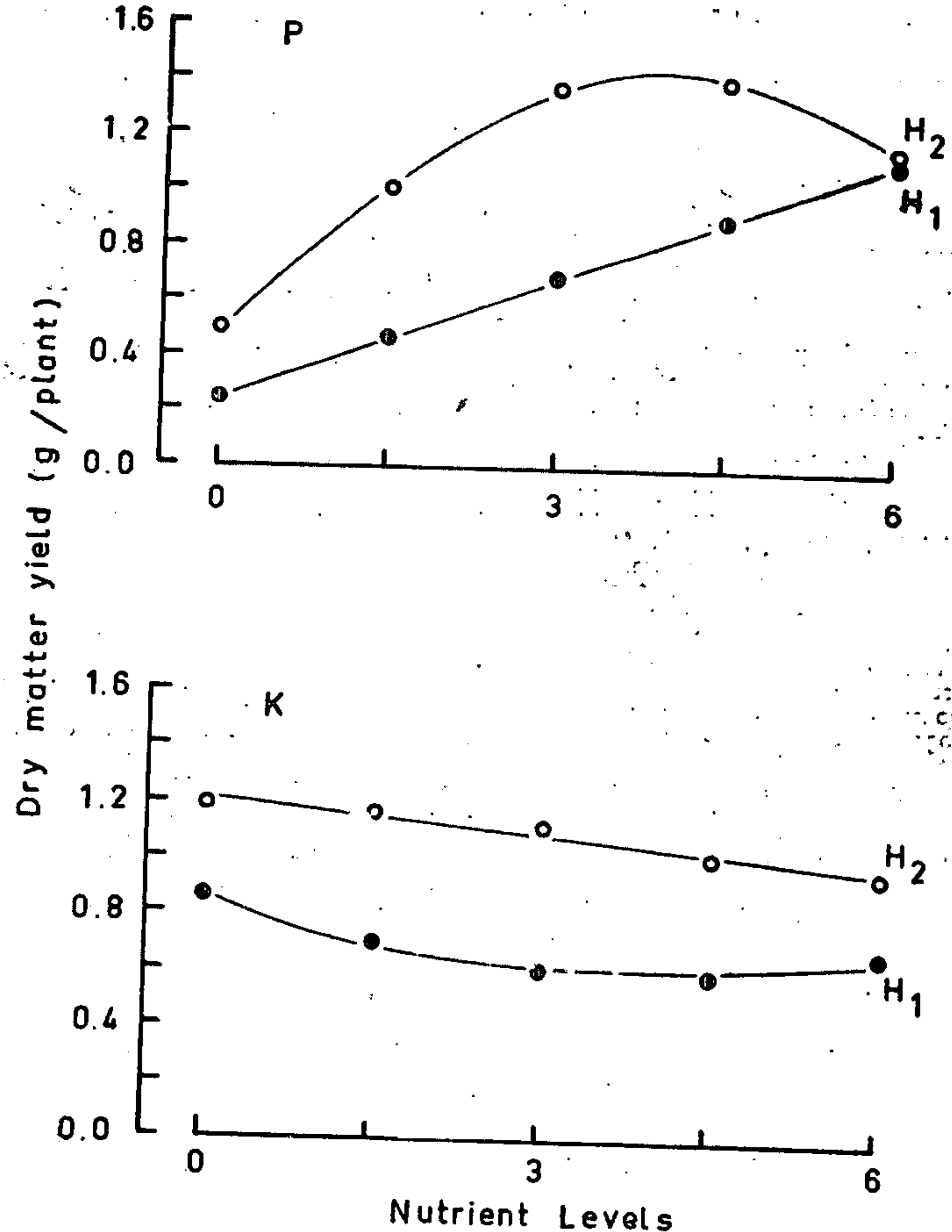

FIGURE 5—Yield of *P. lathyroides* to various levels of P, K and Mg at successive harvests.

of magnesium on the response to the levels of phosphorus was less marked. In general there was a curvilinear response to the various levels of phosphorus. The level of phosphorus at which maximum response was obtained decreased, and the depression at the highest level of phosphorus increased with increase in the level of magnesium (*Fig.* 7).

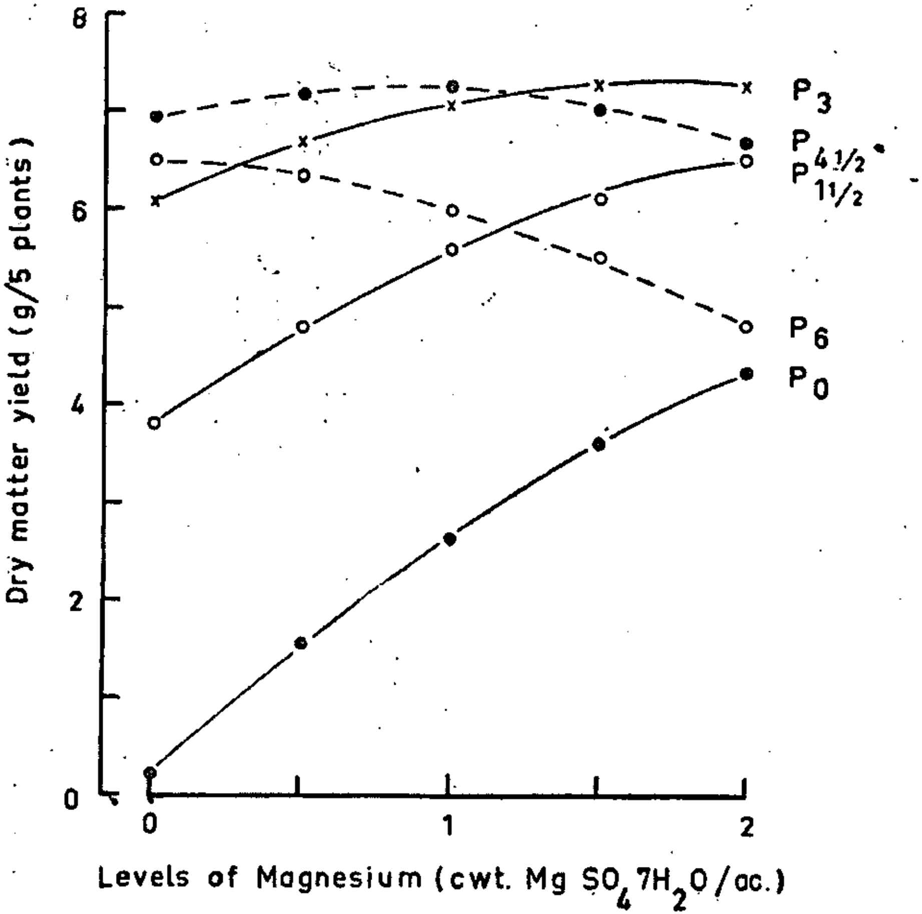

FIGURE 6—The yield of *P. lathyroides* to levels of magnesium at successive levels of phosphorus.

In the interaction of potassium and magnesium the effects were almost typical, in that, in the absence of one nutrient (K) the response to the various levels of the other (Mg) was almost linear, and at the highest level of the first nutrient (K_6) the response to the levels of the second nutrient (Mg) was an almost linear depression (Fig. 8 and 9).

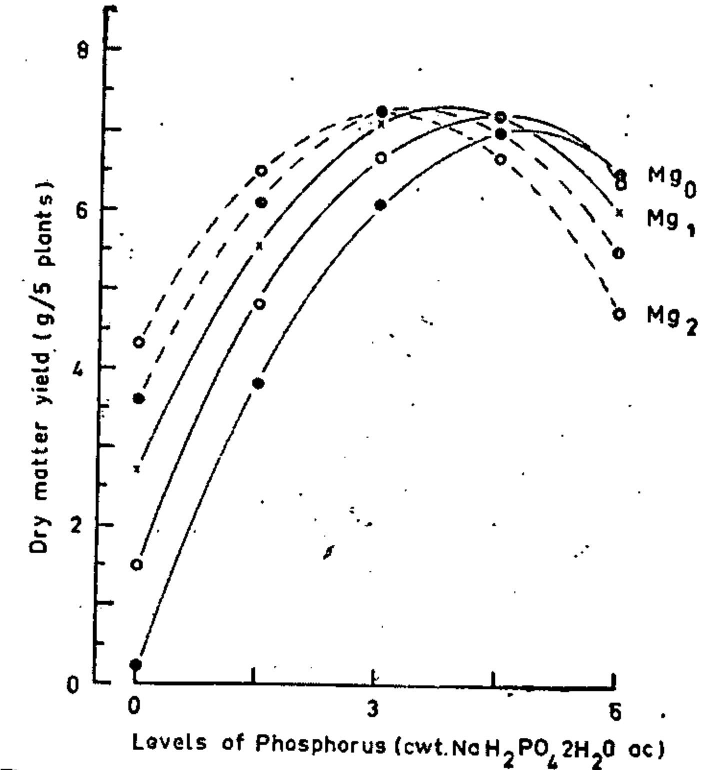

FIGURE 7—The yield of *P. lathyroides* to levels of phosphorus at successive levels of magnesium.

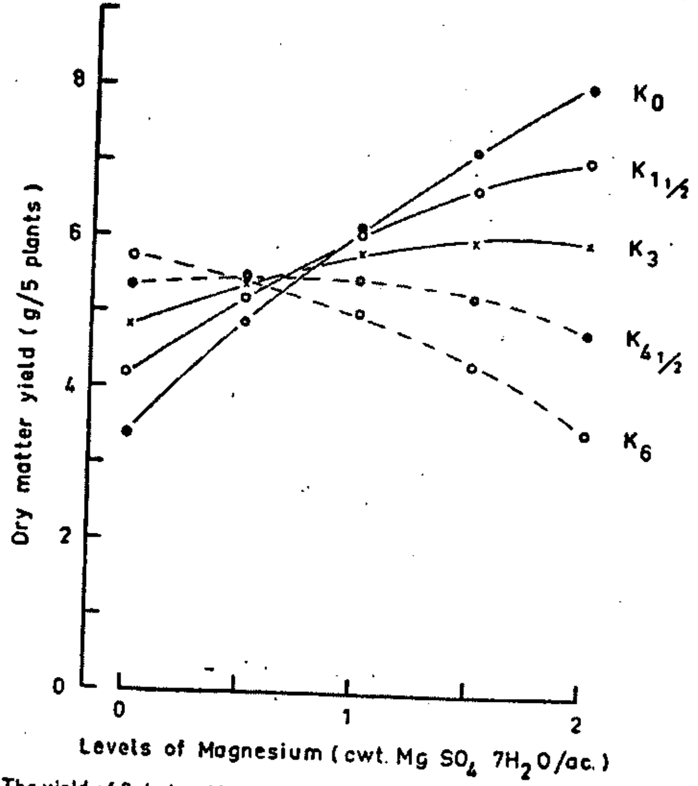

FIGURE 8—The yield of *P. lathyroides* to levels of magnesium at successive levels of potassium.

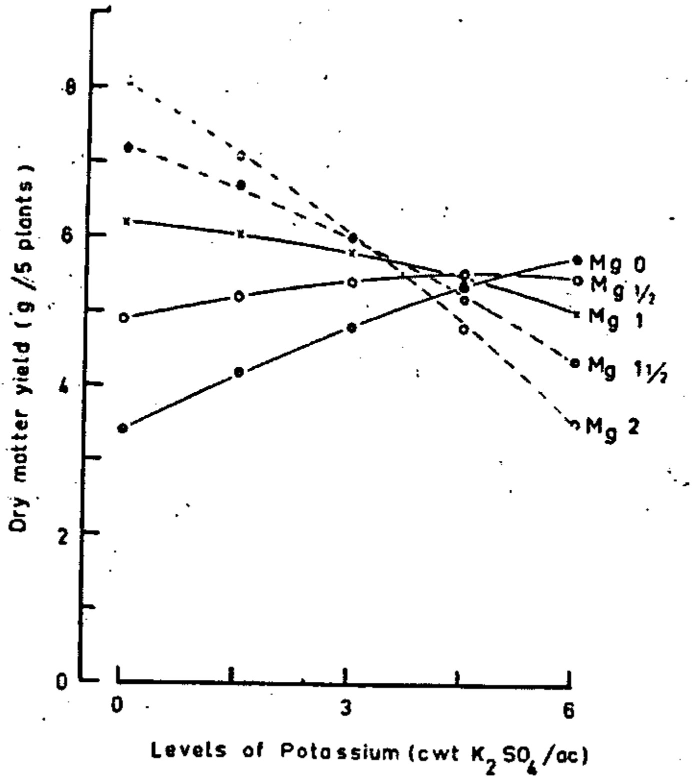

FIGURE 9—The yield of *P. lathyroides* to levels of potassium at successive levels of magnesium.

The yield function in terms of the various nutrients were as follows :—

Harvest 1. $y = -0.19+0.24P -0.00 K+0.64 Mg-0.00P^2+0.02 K^2-0.05 Mg^2-0.01PK-0.08 PMg-0.12 KMg.$

Harvest 2. $y = -0.28+0.59 P+0.13 K+0.92 Mg-0.06 P^2-0.01 K^2-0.08 Mg^2-0.01 PK-0.10 PMg-0.12 KMg.$

The optimum dosage for maximum yield at the second harvest was :—

Phosphorus	4.26 cwt $NaH_2PO_4 . 2H_2O$/ac.
Potassium	3.63 cwt K_2SO_4/ac.
Magnesium	0.53 cwt $MgSO_4 . 7H_2O$/ac.

(*f*) Optimum dosage of boron in presence and absence of calcium.

At all stages of growth calcium was found to be very essential for the growth of *M. Sativa*, so much so that following first harvest there was hardly any regrowth in absence of calcium and after the second harvest nearly all plants died (*Table 9*).

TABLE 9

Mean dry matter yield (g/plant) of *M. sativa* in presence and absence of calcium.

	H_1	H_2	H_3
Ca_0	0.275	0.043	0.010
Ca_{10}	0.874	1.125	0.475
All sig. at 0.1%			

Thus the response to boron is best studied in presence of calcium only. Boron had significant effect at all harvests. There was a high response to the first level of applied boron (B_3). Thereafter there was a progressive depression with increase in the level of boron (*Fig. 10*). Plate I shows the effect of boron on *M. sativa*.

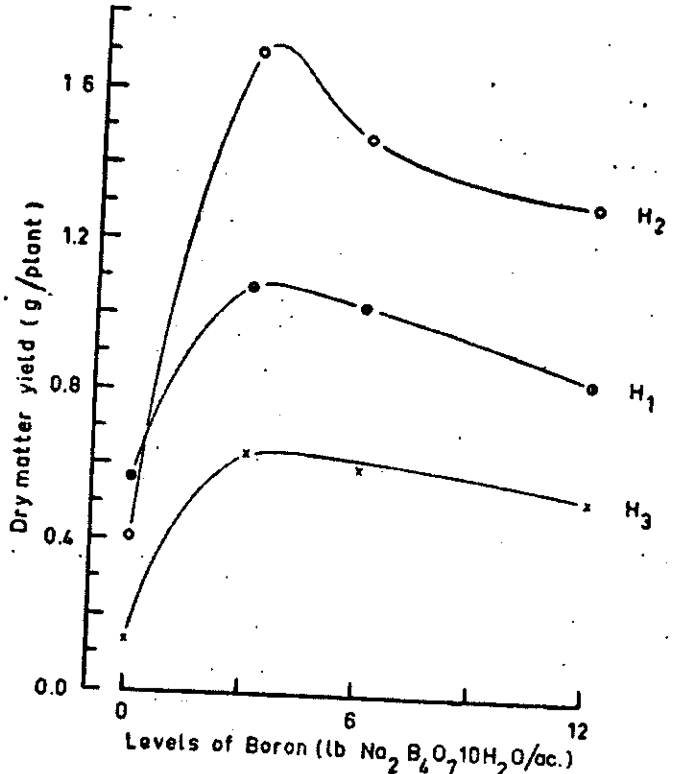

FIGURE 10—The yield of *M. sativa* to levels of boron at successive harvests.

DISCUSSION

The Gonapinuwela gravel was found to be deficient in nitrogen, phosphorus, potassium, magnesium and boron. In this respect it is similar to the lateritic gravel at Mattegoda (Santhirasegaram et al (1966). Both soils require the addition of alkaline substances like $CaCO_3$ or $Ca(OH)_2$ to raise the pH for satisfactory growth of species demanding a high soil pH. This pattern of fertilizer requirement may be considered to be typical of the lateritic gravel of the low country Wet zone of Ceylon. The lateritic gravel is also by far the most extensive soil type in this region.

In the absence of adequate application of nitrogenous fertilizer to this soil relative yields dropped to 17% and then appeared to reach an asymptote. Ammonium nitrate gave best response while ammonium sulphate and urea were less effective and with repeated application and time their effectiveness further decreased. It is to be noted that their effect was measured in presence of added calcium carbonate. Ammonium sulphate is known to reduce the pH of the soil on application and repeated application particularly when the residual sulphate is not removed by leaching could very well result in considerable lowering of the soil pH. In the case of urea, the pH rises considerably on application and in presence of lime this would result in some atmosphoric loss of nitrogen through volatolization of the ammonia formed. With time however the pH decreases and the final effect is a lowering of the soil pH, though less marked than in the case of ammonium sulphate (Santhirasegaram, unpublished). Thus the relative inefficiency of these two forms of nitrogen compared to ammonium nitrate could well be due to a combined effect of these two factors, the effect on soil acidity being more marked.

At the early stages of growth phosphorus had a very big effect, which however decreased with time. This changing pattern has been shown to be due to the effect of residual phosphate fertilizers applied to the soil in the past (Santhirasegaram 1966 a). Over the length of time the response to phosphorus was studied there was no indication as to when the relative yield in absence of phosphorus would reach an asymptote, but from experience with other soils, it is highly probable that this soil would fall into the second group which has received only moderate amounts of phosphatic fertilizers in the past (Santhirasegaram 1966 a).

The response to potassium with time was of a reverse nature to that of phosphorus. The relative yield at "thinnings" was 99%, which dropped linearly with time reaching 8% at the third harvest. Such a pattern of response to potassium has been observed with nearly all soils studied. Paltridge and Santhirasegaram (1957) suggested that this was due to fixation of potassium with wetting of the soil. However Santhirasegaram (1966 b) was unable to detect any change in the potash extracted from soils kept wet for different lengths of time. While this study needs further confirmation it is highly probable that the answer to the plant behaviour may well lie in the physiology of potassium in the plant itself.

Calcium had very little effect except in the case of *S. indicum* and *M. sativa*; both species are known to require a high soil pH for satisfactory growth. On the basis of soil pH the interaction of nitrogen ($(NH_4)_2SO_4$) and calcium ($CaCO_3$) on the growth of *S. indicum* could be explained.

This soil is not deficient in sulphur. The behaviour of magnesium had been very interesting. The interaction of magnesium with phosphorus is contrary to expectation and the effect was mainly due to phosphorus on magnesium. It must be noted that phosphorus was applied as $NaH_2PO_4 . 2H_2O$, and antagonism between Na^+, and Mg^{++}, is well known. Though it is not possible to separate the effect of Na^+ and $H_2PO_4^-$ ions on Mg^{++} in this experiment, it is at least highly probable that much of the effect on magnesium could have been caused by sodium rather than by phosphorus. In the interaction of magnesium with potassium the effect has been mutual, usually these two ions are antagonistic resulting in a negative correlation.

The soil is deficient in boron particularly in relation to legume growth. All other minor nutrients appear to be available in sufficient quantities.

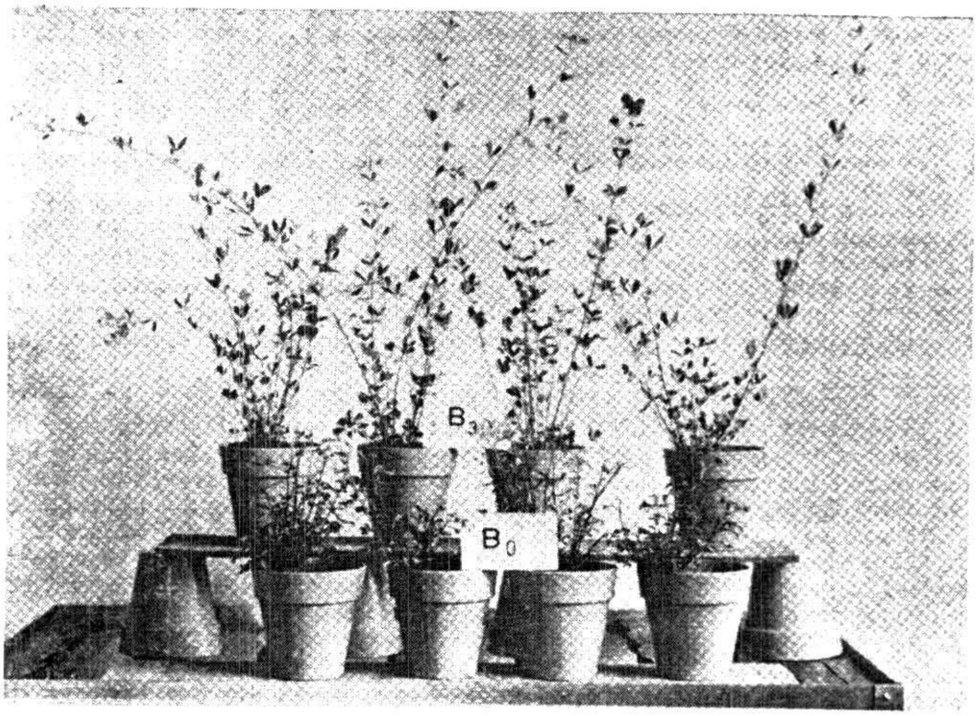

PLATE IA—Growth of *M. sativa* in B_0 and B_3 pots prior to the second harvest. Both were in presence of calcium.

PLATE 1B—Effect of boron deficiency on *M. sativa.*

In as far as providing some indication from the point of view of nutrient disorders for the "leaf scorch" condition of coconut palms prevalent in this area, these studies are negative. The nutrient deficiencies and the patterns of responses are similar to lateritic soil types of other regions where the coconut palms are free of this condition.

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APPENDIX

Design of Experiment E

" In studies involving the experimental determination of critical levels of plant nutrients and optimum rates of fertilizer application, the need for the consideration of joint effects of other nutrients has long been realised. When such joint effects or interactions exist, characterisation of the response surface is essential for the realistic evaluation for the responses. The use of the complete factorial experiment provides a means of estimating the response surface ; but the number of treatment combinations required, specially where more than two nutrients or factors are involved, has often prohibited their use in field and greenhouse research.

Where a polinominal model may be used to approximate a response surface, new experimental designs, known as the composite and rotatable designs, have been developed by Box and Hunter. In these designs, the treatment combinations are selected to allow estimation of the parameters of the model. These designs use considerably fewer treatment combinations for the experiment than required by the complete factorial arrangement."(Hader et al 1957).

Such a design has been used in this experiment, where 3 nutrients (P, K & Mg) were tested at 5 levels each.

Treat. No.	*P*	*K*	*Mg*	*Coded Levels* *P*	*K*	*Mg*
1	1½	1½	½	—1	—1	—1
2	1½	1½	1½	—1	—1	+1
3	1½	4½	½	—1	+1	—1
4	1½	4½	1½	—1	+1	+1
5	4½	1½	½	+1	—1	—1
6	4½	1½	1½	+1	—1	+1
7	4½	4½	½	+1	+1	—1
8	4½	4½	1½	+1	+1	+1
9	3	3	1	0	0	0
10	0	3	1	—2	0	0
11	6	3	1	+2	0	0
12	3	0	1	0	—2	0
13	3	6	1	0	0	—2
14	3	3	0	0	0	—2
15	3	3	2	0	0	+2
16	0	6	2	—2	+2	+2
17	6	0	2	+2	—2	+2
18	6	6	0	+2	+2	—2

The response surface is characterised by the following function :—

$$y = a_0 + b_1P + b_2K + b_3Mg + b_4P^2 \\ + b_5K^2 + b_6Mg^2 + b_7PK + b_8PMg + b_9KMg$$

The " b " coefficients are estimated and tested for significance by the usual multiple regression analysis technique.

HADER, R. J., HARWARD, M. E., MASON, D. D., MOORE, D. P. (1957) *Proc. Soil Sci. Soc. Am.* **21.**