
STUDIES ON THE NUTRIENT STATUS OF SOME COCONUT SOILS IN CEYLON

3. THE FOREST SOIL AT "AMBAKELLE"

(A) Preliminary Experiments

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1. INTRODUCTION

THIS paper is one of a series recording data from experiments with some of the more important coconut soils in Ceylon. Those experiments were designed to give basic information on the nutrient status of each soil, with a view to more effective use of fertilizers on coconuts, and to correction of nutrient deficiencies that might be a limiting factor in the growth and selection of desirable pasture plants. The type of experiment and techniques employed have all been described in a previous article (*Tropical Agriculturist*, Vol. CXIII, 1957).

Ambakelle is situated in the Chilaw District of Ceylon. It is on a coastal plain, approximately four miles from the western coastline and 52 miles north of Colombo. The natural vegetation is a tropical forest, but in 1955 a small area of 200 acres was cleared and has since been developed as an 'Isolated Seed Garden', where new varieties of coconut can be grown without serious risk of cross-pollination with other varieties, or with those used for commercial crops in that district. Information on the nutrient status of that soil—which may be typical of comparatively large areas in the dry zone—is of obvious importance to the overall program of C. R. I. research.

The soil at Ambakelle is a light sandy loam generally about five feet in depth overlying a layer of rounded pebbles which is itself about two feet in thickness. Beneath those pebbles is a hard-pan 6 to 12 inches thick and the sub-soil is a stiff brownish clay. In order to avoid any complication from admixture of ash or forest debris after clearing, the soil used in these experiments was collected from a number of locations within the undisturbed forest. Those samples were then transported to the laboratory, thoroughly

mixed, and after removal of any coarser vegetable matter (leaves, stems and larger roots) that 'soil' was stored in a large wooden bin, thereby providing uniform material for use in a number of pot experiments.

The pots were all 6 inch polysterene flower pots:—each containing approximately 2,000 gms. (dry weight) of soil. The response to any nutrient was measured in terms of the dry weight of plants grown in every pot. All pots were watered daily, their water content being brought to a constant level (85 per cent. field capacity) by weight. The water was filtered, passed through a commercial water softener, distilled and re-distilled before use. The final distillation was in 'pyrex' glassware.

The test plants were a perennial pasture grass (*Paspalum commersonii* Lam.) and two legumes (*Phaseolus lathyroides* L. and *Medicago sativa* L.)

2. EXPERIMENTAL

A. Experiment 1

(1) **Objective.**—To measure the effect of major nutrients (N.P.K.Ca. and Mg.), and of 'X' (a mixture of Fe. Cu. Zu. and Mn.) on the yield of *Paspalum commersonii* growing on forest soil from Ambakelle.

(2) **Design and Procedure.**—This was a 2⁶ factorial experiment with only one replicate of each treatment. Calcium was applied as CaCO₃ (10 cwt/acre, mixed with the upper 1½ inches of soil); all other nutrients were applied in solution, and in forms and doses enumerated in Table I.

TABLE I.—Forms and rates of fertilizer applied in Experiment 1

Designation	Chemical	Rate of Application/Acre	
N ₅	(NH ₄) ₂ SO ₄	5 cwt. ≡ 118 lb. N.	+ 135 lb. S.
P ₃	NaH ₂ PO ₄ .2H ₂ O	3 cwt. ≡ 67 lb. P.	+ 49 lb. Na.
K ₃	K ₂ SO ₄	3 cwt. ≡ 150 lb. K.	+ 70 lb. S.
Mg1½	MgSO ₄ .7H ₂ O	1½cwt. ≡ 18 lb. Mg.	+ 21 lb. S.
Fe ₁₄	FeSO ₄ .7H ₂ O	14 lb. ≡ 2.8 lb. Fe.	+ 1.6 lb. S.
Cu ₁₄	CuSO ₄ .5H ₂ O	14 lb. ≡ 3.6 lb. Cu.	+ 1.8 lb. S.
Zn ₁₄	ZnSO ₄ .7H ₂ O	14 lb. ≡ 3.0 lb. Zn.	+ 1.6 lb. S.
Mn ₁₄	MnSO ₄ .4H ₂ O	14 lb. ≡ 3.5 lb. Mn.	+ 2.0 lb. S.

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The *Paspalum* was planted on 19th January, 1957, and harvested four times, viz.—on 11th March, 4th April, 8th May and 5th June, 1957. Additional nutrients were applied as follows:—

5th March, 1957—3 cwt./acre K_2SO_4 was applied to all pots with added K.
Total dose then \equiv 300 lb./acre of K.

7th March, 1957—5 cwt./acre $(NH_4)_2SO_4$ was applied to all pots with added N.
Total dose then \equiv 236 lb./acre of N.

3rd April, 1957—1½ cwt./acre K_2SO_4 was applied to all pots with added K.
Total dose then \equiv 375 lb./acre of K.

2½ cwt./acre $(NH_4)_2SO_4$ was applied to all pots with added N. Total dose then \equiv 295 lb./acre of N.

22nd April, 1957—3 cwt./acre $NaH_2PO_4 \cdot 2H_2O$ was applied to all pots with added P. Total dose then \equiv 134 lb./acre of P.

25th April, 1957—2½ cwt./acre $(NH_4)_2SO_4$ was applied to all pots with added N. Total dose then \equiv 354 lb./acre of N.

9th May, 1957—1½ cwt./acre of K_2SO_4 was applied to all pots with added K.
Total dose then \equiv 450 lb./acre of K.

15th May, 1957—2½ cwt./acre $(NH_4)_2SO_4$ was applied to all pots with added N. Total dose then \equiv 413 lb./acre of N.

The full dosage for pots receiving N.P.K. and Ca. was therefore—

17.5 —wt./acre $(NH_4)_2SO_4$ — 413 lb./acre of N.

9.0 cwt./acre K_2SO_4 — 450 lb./acre of K.

6.0 cwt./acre $NaH_2PO_4 \cdot 2H_2O$ — 134 lb./acre of P.

10.0 cwt./acre $CaCO_3$ — 448 lb./acre of Ca.

(iii) **Results.**—Magnesium and 'X' had no significant effect on yields in any harvest, and mean yields for four replicates (nil, Mg., X and MgX) are recorded in Table II.

TABLE II. *Experiment 1 showing mean yields and level of significance for all treatments affecting the yield of Paspalum commersonii in four successive harvests. (N.B. Significance at 5 per cent not recorded.)*

Harvest	Treatment	Nil	N.	P.	N.P.	Effective Treatments and Level of Significance Per cent.
(1) Age 51 Days	nil nil	0.95	1.56	1.91	7.82	K. (0.1) P. (0.1) N. (0.1) HARV. (0.1) K.P. (0.1) K.N. (0.1) P.N. (0.1) K.H. (0.1) P.H. (0.1) N.H. (0.1) Ca.H. (0.1) K.P.N. (0.1) K.P.H. (0.1) K.N.H. (0.1) P.N.H. (0.1) N.Ca.H. (0.1) K.P.N.H. (0.1)
	K.	0.62	2.31	2.23	8.49	
	Ca. nil	0.69	1.04	1.88	6.39	
	K.	0.72	1.98	1.97	6.91	
(2) Age 75 Days	nil nil	1.19	2.26	1.18	3.63	
	K.	1.27	2.89	1.07	7.61	
	Ca. nil	1.33	2.00	1.22	4.06	
	K.	1.20	2.99	1.04	7.05	
(3) Age 109 Days	nil nil	1.55	4.85	1.91	2.55	
	K.	1.45	5.37	1.69	12.01	
	Ca. nil	1.67	4.78	1.53	3.97	
	K.	1.44	5.45	2.03	11.65	
(4) Age 147 Days	nil nil	0.88	0.11	0.98	0.02	
	K.	0.70	1.13	0.63	4.66	
	Ca. nil	0.84	1.46	0.84	0.15	
	K.	0.78	1.61	0.68	5.64	

The data show that in all four harvests N. P. and K. together had a very big effect on yield. The same three nutrients alone or in other combinations had a somewhat smaller effect. Calcium had very little effect, except during the first harvest:—when it was responsible for some depression in yield. That pattern of responses was consistent over all four harvests. Mean yields for two replicates ('nil' and Mg.) and for 32 treatments are shown diagrammatically in Fig. 1 and 2.

(a) **First Harvest.**—In the first harvest N.-alone increased yields by approximately 64 per cent. ; N.P., N.K. and N.P.K. gave increments of 723, 143 and 794 per cent. respectively. K.-alone had no significant effect ; P.-alone, and P.K. gave increments of 101 and 135 per cent.

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Experiment 1—Diagram showing mean yield for each of 32 treatments in four successive harvests *Paspalum commersonii*

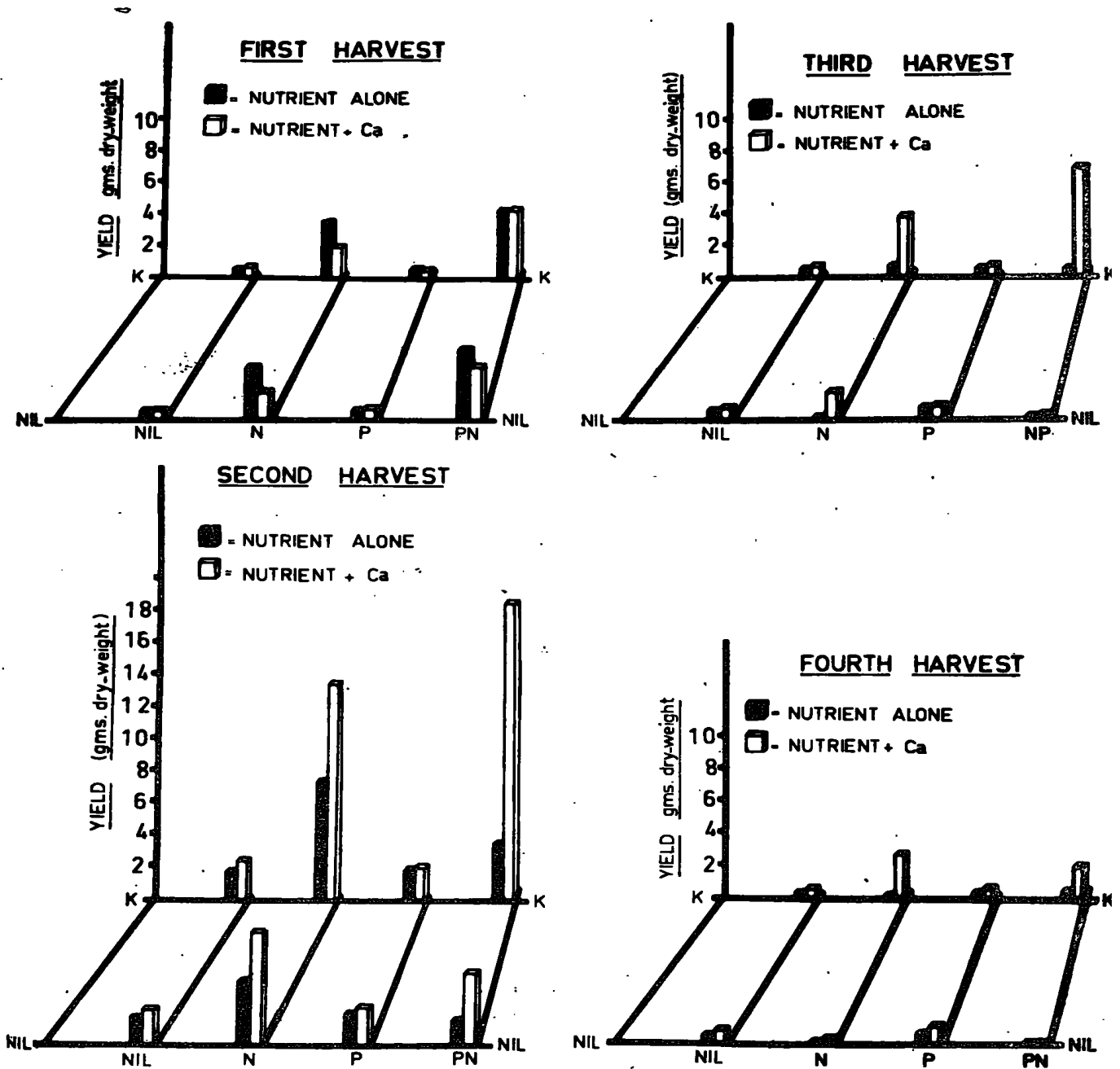


Fig. 1

Calcium was in all cases responsible for some depression in yield, and on a basis of 100 for each of eight N.P.K. treatments, the mean relative yield for Ca. was 85 ± 5.4 .

(b) **Second Harvest.**—In the second harvest, N.-alone increased mean yields by 90 per cent. ; N.P., N.K. and N.P.K. gave increments of 205, 144, and 540 per cent., respectively. P.-alone, K.-alone and P.K. had no significant effect on yield.

Calcium had no significant effect on yield in any combination with N., P. or K.

(c) **Third Harvest.**—In the third harvest N., N.K., N.P. and N.P.K. gave increments of 213, 246, 65 and 675 per cent. respectively ; K.-alone and P.-alone had no significant effect ; P.K. gave a small increment of 23 per cent.

Calcium had no significant effect.

(d) **Fourth Harvest.**—In the fourth harvest, and with N.-alone, or with N.P., three out of four plants died ; N.K. increased mean yields by 28 per cent., N.P.K. by 430 per cent ; P.-alone, K.-alone and P.K. had no beneficial effect (increment of 11 per cent. and decrements of 20 and 28 per cent. respectively.)

Calcium had no significant effect on yield.

(iv) **Discussion**—The data from Experiment 1 have shown that plants growing on this soil would suffer from an acute deficiency of N.P. and K., but unlike the lateritic soils at 'Bandirippuwa' (see C.R.I., Bulletins 11, 12 and 13), and except for an increasingly acute deficiency of K., the pattern of responses was consistent over four harvests (i.e., 147 days, or approximately five months).

Calcium deficiency was not evident until the fourth harvest, and there was no deficiency of Mg., or of minor elements (Cu. Zn. Mn. or Fe.).

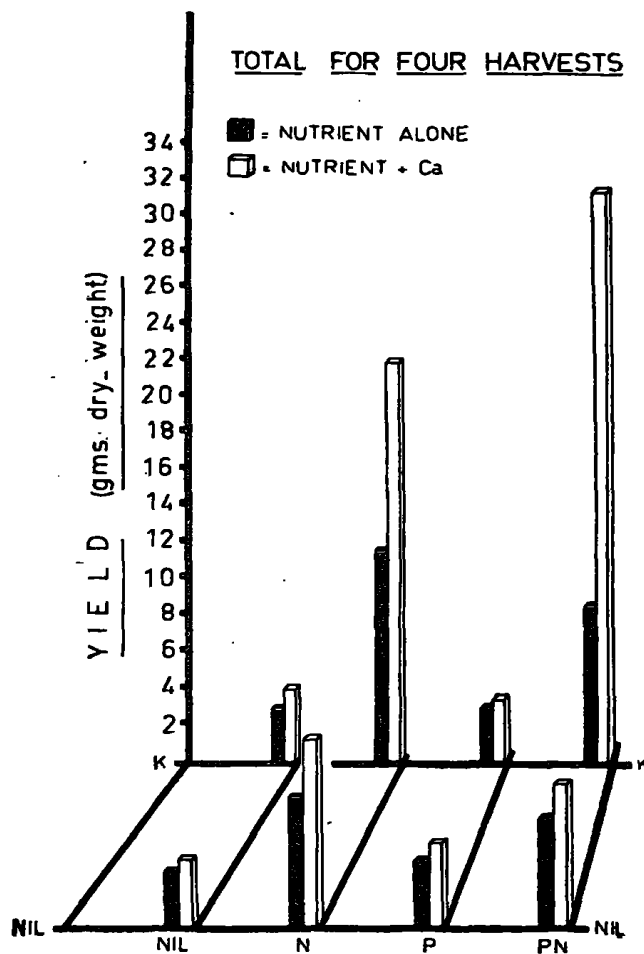


Fig. 2
Experiment 1—Diagram showing cumulative yields from four successive harvests of Paspalum commersonii

In order to obtain some measure of these naturally occurring deficiencies, the data from this experiment were re-analysed, and mean yields were then expressed as a percentage of that obtained with the full fertilizer treatment, (N.P.K.Ca.). Those data were then plotted as a graph showing *relative yields* in the absence of individual nutrients. In order to obtain some measure of reliability, the data from a number of replicates (i.e., corresponding values for all treatments that had no effect on yield) were separately computed. *Mean relative yields*, and standard deviations were then calculated from these individual values. These data for each of the four harvests are shown diagrammatically in Fig 3.

(a) **No Phosphorus.**—In absence of P., mean relative yields did not exceed a value of 47 ± 5 per cent. and except for a slight drop in the fourth harvest there was no significant difference between mean relative yields for successive harvests.

The data therefore show that without some application of phosphorus, no amount of fertilizer would give yields exceeding 40 per cent. of the potential level of production on this soil.

(b) **No Nitrogen.**—Nitrogen was at all times acutely deficient, and mean relative yields did not exceed a value of 29 ± 2.9 per cent. in the first harvest. In the second, third and fourth harvests they did not exceed 17 per cent., and there were no significant differences between harvests.

(c) **No Potassium.**—In absence of potassium, mean relative yields decreased steadily from an initial value of 95 ± 6.8 per cent. in the first harvest, to 4 ± 2.4 per cent. in the fourth harvest. The data suggest that there were no reserves of normally unavailable K. ; or, at least, no evidence of any conversion to an available form.

(d) **No Calcium.**—There was no evidence of any deficiency of calcium, except in the fourth harvest, when the mean relative yield dropped to 83 ± 5.5 per cent. In the first harvest the addition of Ca. caused some depression in yield (i.e., mean relative yield exceeding 100 per cent. :—see C.R.I., Bulletin 13), and that effect persisted in reduced degree through the second harvest. In the third harvest there was no effect from Ca.

The data therefore suggest that plants growing on this soil would not suffer from any initial deficiency of calcium, and that any application of lime should be withheld, pending some further experiments with similar soil that has been under crops, or pasture, for one or two years.

B.—Experiment 2

(i) **Objective.**—To measure the effect of sulphur on two species growing on Ambakelle Forest soil.

Experiment 1. Diagram showing the trend of mean relative yields (\pm Standard deviations) in successive harvests of *Paspalum commersonii*

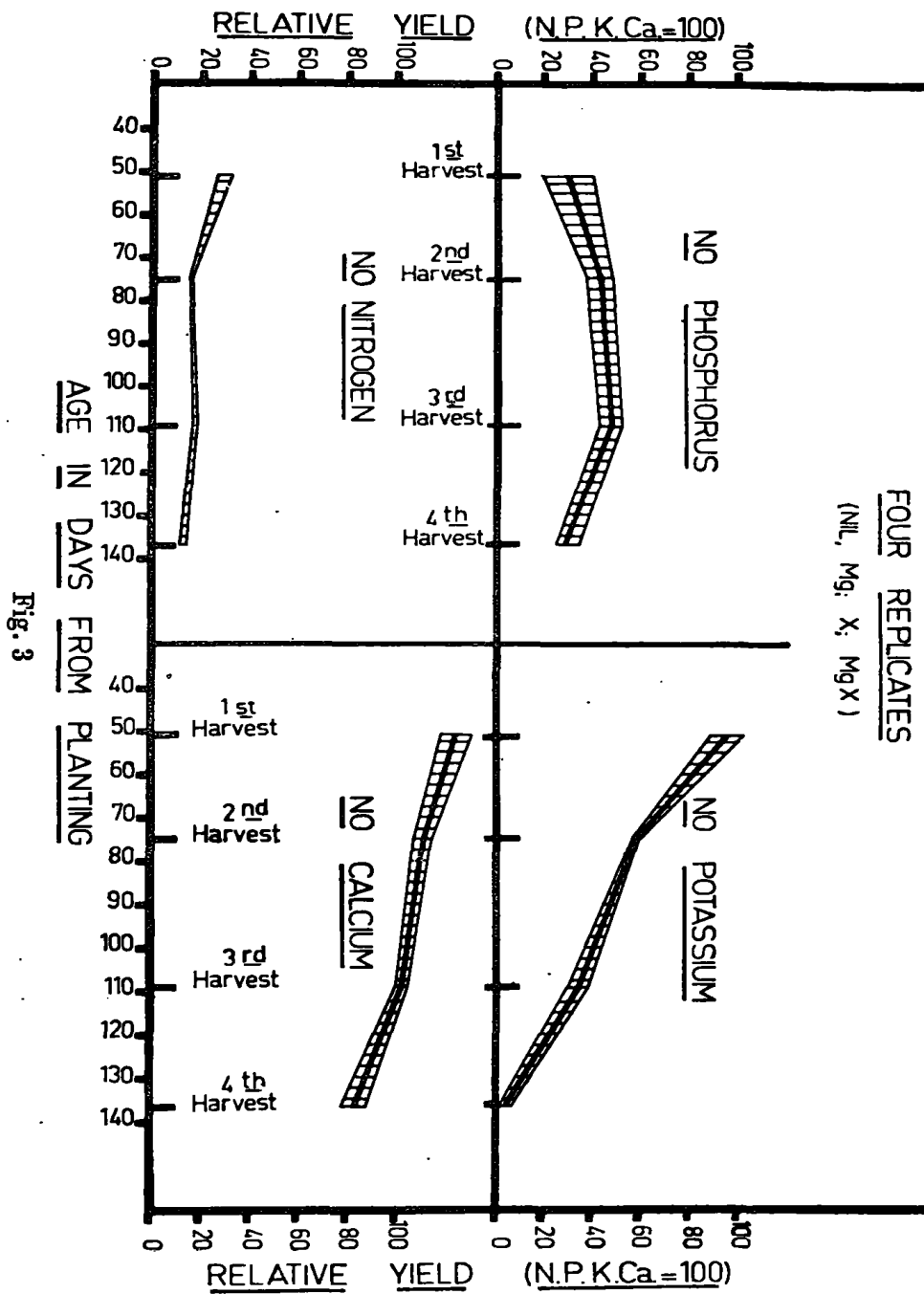


Fig. 3

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(ii) **Design and Procedure.**—This was a simple comparison of two treatments 'nil' and 'sulphur' using two species (*Paspalum commersonii* and *Phaseolus lathyroides*). There were ten formulations comprising five mixtures containing sulphur (i.e. $(\text{NH}_4)_2\text{SO}_4$; MgSO_4 ; CaSO_4 ; H_2SO_2 and S_4) and five with no sulphur (i.e. NH_4NO_3 ; MgCl_2 ; CaCO_3 ; HCl and nil). All formulations contained the same amounts of N, Mg. and Ca., and all pots were given a basal dressing of K. (5 cwt./acre KCl) and P. (3 cwt./acre $\text{NaH}_2\text{PO}_2\text{H}_2\text{O}$). The basic treatment was S_4 (0.175 gms./pot \equiv 123 lb./acre of S.). The *Phaseolus* was planted on 1st June, and the *Paspalum* on 12th June, 1957. Both species were harvested on 24th July, 1957.

(iii) **Results.**—Individual yields are recorded in Table III. Sulphur did not improve the yield of either species.

TABLE III. *Experiment 2. showing individual and mean yields for two species*

Species	Treatment	$(\text{NH}_4)_2\text{SO}_4$	MgSO_4	CaSO_4	H_2SO_4	S_4	MEAN
		NH_4NO_3	MgCl_2	CaCO_3	HCl	Nil	
Paspalum	nil	2.66	1.60	3.12	1.84	2.07	2.26
	S	1.62	1.68	1.71	1.91	2.18	1.82
Phaseolus	nil	1.14	1.41	1.32	1.08	1.20	1.23
	S	1.57	0.93	0.95	0.91	1.54	1.18
Mean	nil	1.90	1.50	2.22	1.46	1.63	1.74
	S	1.59	1.30	1.33	1.41	1.86	1.50

C.—Experiment 3

(i) **Objective.**—To measure any effect from increasing dosage of boron, and of calcium on the yield of two species growing on Ambakelle Forest soil.

(ii) **Design and Procedure.**—This was a $4 \times 3 \times 2$ factorial experiment using two species (*Phaseolus lathyroides* and *Medicago sativa*). All pots were given a basal dressing of N., P., K., Mg., Fe., Cu., Zn., Mn., and Mo. Nitrogen was applied as NH_4NO_3 (3 cwt./acre); potassium as K_2SO_4 ($4\frac{1}{2}$ cwt./acre); all other nutrients were applied in forms and doses enumerated in Table 1. There were three levels of calcium:—0, 10 and 20 cwt./acre CaCO_3 ; and four of boron:—0, 3, 6 and 9 lb./acre $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10\text{H}_2\text{O}$.

For this experiment, and in order to avoid boron contamination (i.e., from 'pyrex' glassware) all water was finally distilled in chromium plated apparatus.

Both species were planted on 4th June, 1957. The *Phaseolus* was harvested twice, on 15th July and 1st August, 1957. The *Medicago* was harvested once on 1st August, 1957, but on 16th July, the number of plants per pot—originally two—was reduced to one, and plants removed (designated 'thinnings') were weighed to give some additional data.

(ii) *Results*—Individual yields are recorded in Table IV.

TABLE IV. *Experiment 3 showing individual yields and level of significance for all treatments affecting the yield of two species*

Species Harvest		Treatment	Nil	B ₃	B ₆	B ₉	Effective Treatment and Level of Significance
M E D I C	Thinnings Age 42 Days	Ca ₀	0.25	0.24	0.16	0.10	Ca. (5.0) Species (0.1) Harv. × Spec. (0.1)
		Ca ₅	0.27	0.21	0.18	0.17	
		Ca ₁₀	0.22	0.22	0.12	0.12	
A G O	(1) Age 58 Days	Ca ₀	0.89	1.22	0.59	0.38	
		Ca ₅	0.70	0.97	0.42	0.32	
		Ca ₁₀	1.15	0.60	0.68	0.60	
P H A S E O L U S	(1) Age 41 Days	Ca ₀	2.68	2.07	2.02	2.00	
		Ca ₅	1.85	1.73	1.58	1.74	
		Ca ₁₀	1.39	1.82	1.94	1.92	
	(2) Age 58 Days	Ca ⁰	1.15	1.40	1.68	1.68	
		Ca ₅	1.08	0.99	0.69	1.15	
		Ca ₁₀	0.77	1.17	1.13	1.57	
		TOTAL	12.40	12.64	11.19	11.75	

Boron had no significant effect on the yield of either species. Calcium was responsible for some depression in yield (mean values of — 24 and — 16 per cent. for Ca₅ and Ca₁₀ respectively).

3. SUMMARY AND CONCLUSIONS

2. The data from three experiments have shown that plants growing on Ambakelle Forest soil would suffer from an acute deficiency of N. P. and K.

2. In the early stages of growth there was no apparent deficiency of calcium, and plants of *Paspalum commersonii* growing on 2,000 gms. of soil yielded an equivalent of 7.8 tons (dry weight) per acre, in 104 days. In a later harvest (i.e., after 137 days) there was some improvement:—(17 per cent. increment in yield) from an original dressing of 10 cwt./acre CaCO₃.

3. There was no evidence of any deficiency of magnesium, or sulphur, or of minor elements :—copper, zinc, manganese, iron or boron, and no visual symptoms of molybdenum deficiency were observed.

4. Deficiencies of N. P., and K. were acute and omission of any one of those three nutrients from the complete fertilizer caused a very great reduction in yield.

In absence of phosphorus, yields were reduced by 60 per cent.

Omission of nitrogen caused an 85 per cent. reduction in yield.

With no potassium, yields declined steadily from an initial value of 95 per cent. to a final value of 2.5 per cent.

5. Correct dosages—i.e., the amounts of individual nutrients which are necessary for satisfactory plant growth—have not been determined, but in these experiments very large doses (6 cwt./acre $\text{NaH}_2\text{PO}_4 \cdot 2\text{H}_2\text{O}$; 9 cwt./acre K_2SO_4 ; and 17.5 cwt./acre $(\text{NH}_4)_2\text{SO}_4$ were used in the complete fertilizer, with no adverse effect.

6. The data from these experiments provide clear evidence that a ' virgin ' forest soil in Ceylon can be relatively infertile (see Plate I) ; and that forest growth does not necessarily build, or restore, a high level of soil fertility.

7. It may be a point of some practical importance that with adequate supply of available P, K, Ca, and water, legumes (*Phaseolus lathyroides* and *Medicago sativa*) grew very well in this soil.

4. ACKNOWLEDGMENT

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The senior author wishes to express appreciation of the extensive facilities for research provided by the Coconut Research Institute, and by all who are concerned in its administration.

[PLATE I]



Plants of Paspalum Commersonii grown on forest soil from Ambakelle with and without the addition of plant nutrients (N., P., K., Ca). Photo taken one week before third harvest of Experiment I.