STUDIES ON THE NUTRIENT STATUS OF SOME COCONUT SOILS IN CEYLON

1. THE LATERITIC SOILS OF "BANDIRIPPUWA" ESTATE

B. Preliminary Experiments with "Lateritic Loam" and "Lateritic Sand"

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INTRODUCTION

THIS PAPER is one of a series emanating from the Coconut Research Institute Division of Agronomy, and published under a common title, "Studies on the Nutrient Status of some Coconut Soils in Ceylon." It records data from experiments with the "*Lateritic Loam*" and the "*Lateritic Sand*" on Bandirippuwa Estate. The objectives and the techniques employed are in all respects similar to those described in our previous publication.

These two soils were selected as important derivatives of the "*Lateritic Gravel*", which appears to be the parent material from which both are derived. The "*Lateritic Loam*" is a grey loamy sand, which may be one to four feet deep, overlying a more typical laterite. It appears to be an accumulation of what was originally surface soil on adjacent lateritic ridges. The "*Lateritic Sand*" is confined to the valley floors and to flat open country where there is, or has been, freely moving water. It is a grey-white sand overlying kaolinitic clay at a depth of approximately six feet. There is no apparent stratification, and no hard-pan. The surface sand is loose and friable, but the deeper sands are frequently, compressed and partially cemented.

Samples of those soils were collected from a number of places in different areas, and they were thoroughly mixed to provide uniform material for use in pot experiments. Individual samples included all material above a depth of nine inches, but the coarser vegetable matter (stems, leaves and larger roots) were subsequently removed.

That soil was then used to fill a number of 6 inch polysterene flower pots :— each containing approximately 2,000 gms. (dry weights), and 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.

In order to avoid contamination, the water was filtered, passed through a commercial water softener, distilled and re-distilled before use. The final distillation was in Pyrex glass. The test plants were a perennial pasture grass (*Paspalum commersonii Lam.*) and a legume (*Phaseolus lathyroides* L.).

2. EXPERIMENTAL

A. Experiment 1

(i) **Objective.** To measure the effect of major nutrients (N, P, K, Ca and Mg) and of " X " (a mixture of Cu, Zn, Mn, Fe, B and Mo), on the yield of *Paspalum commersonii* growing on " *Lateritic Loam* ".

(ii) **Design and Procedure.** This was a 2^6 factorial experiment, with only one replicate of each treatment. All nutrients were applied in forms and doses enumerated in Table I.

The *Paspalum* was planted on October 5, 1956, and harvested three times, viz. :—on November 6, and December 18, 1956, and on January 21, 1957 : Additional nutrients were applied as follows :—

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

Designation	*Chemical*	*Rate of Application/Acre*							
K_3	K_2SO_4	3	cwt.	≡	150	lb. K	+	70	lb. S
P_3	$NaH_2PO_4 . 2H_2O$	3	cwt.	≡	67	lb. P	+	49	lb. Na
N_5	$(NH_4)_2SO_4$	5	cwt.	≡	118	lb. N	+	135	lb. S
Ca_{10}	$CaCO_3$	10	cwt.	≡	4	cwt. Ca	+		
$Mg_{1\frac{1}{2}}$	$MgSO_4 . 7H_2O$	1½	cwt.	≡	18	lb. Mg	+	22	lb. S
Cu_{14}	$CuSO_4 . 5H_2O$	14	lb.	≡	3.6	lb. Cu	+	1.7	lb. S
Zn_{14}	$ZnSO_4 . 7H_2O$	14	lb.	≡	3 .0	lb. Zn	+	1.6	lb. S
Mn_{14}	$MnSO_4 . 4H_2O$	14	lb.	≡	3.5	lb. Mn	+	2.0	lb. S
Fe_{14}	$FeSO_4 7H_2O$	14	lb.	≡	2.8	lb. Fe	+	1.6	lb. S
B_6	$Na_2B_4O_7 . 10H_2O$	6	lb.	≡	1.0	lb. B	+	1.0	lb. Na
Mo_1	$(NH_4)_5 . Mo_7O_{24} . 4H_2O$	1	lb.	≡	0.53	lb. Mo	+	0.716	lb. N

On December 5, 1956—5 cwt./acre $(NH_4)_2$ SO_4 were applied to all pots with added N Total dose then ≡ 236 lb /acre of N

On December 11, 1956—1½ cwt./acre of K_2SO_4 were applied to all pots with added K. Total dose then ≡ 225 lb./acre of K

On January 16, 1957—5 cwt./acre $(NH_4)_2SO_4$ were applied to all pots with added N. Total dose then ≡ 344 lb./acre of N.

(iii) **Results.** Magnesium and " X " had no significant, or apparent 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 for four replicates (nil, Mg. 'X' and MgX), and level of significance for treatments affecting the yield of* Paspalum commersonii *in three successive harvests. n.b. Significance at 5 per cent. not recorded.*

Harvest	*Treatment*		*Nil*	*P.*	*N.*	*N.P.*	*Effective Treatment*	*Level of Significance. %*
1	nil	nil	1·01	1·27	1·36	3·57	K.	0·1
		K	1·28	1·35	1·32	5·20	N	1·0
Age 42 Days	Ca	nil	0·88	1·33	1·39	3·46	KN.	0·1
		K	1·47	1·38	1·36	5·13	Harvest	1·0
2	nil	nil	0·69	0·68	2·16	2·10	P. Harvest	0·1
		K	0·84	0·64	3·68	3·89	Ca. Harvest	1·0
Age 74 Days	Ca	nil	1·05	0·87	2·91	2·02	P. N. Harvest	0·1
		K	1·22	0·77	3·69	2·92	K. N. Harvest	1·0
3	nil	nil	0·40	0·37	0·02	0·00		
		K	0·37	0·36	2·29	2·46		
Age 108 Days	Ca	nil	0·56	0·61	1·51	0·23		
		K	0·52	0·48	5·75	4·43		

The effect of these four nutrients, and of magnesium, in successive harvests are shown diagrammatically in Fig. 1. Cumulative yields are shown in Fig. 2.

The data show that N. P. K. and Ca all had a very big effect on yield. They were most effective when used in combination, and there were a number of interactions between " nutrients " and " harvest ", which devolved from a hanging pattern of responses in successive harvests. Those responses may be summarized as follows :—

1st Harvest. In the first harvest there was no significant response to N. alone ; P. and K. alone were responsible for small increases (increments of 26 per cent.), and there were very big responses to N.P. (increment of 254 per cent.), and to N.P.K. (increment of 414 per cent.), Neither Ca. nor Mg. had any significant effect on yield.

2nd Harvest. In the second harvest, P. or K. alone had no significant effect on yield, but there was a big response to N. (increment of 213 per cent.), and to N.K. (increment of 432 per cent.) ; N.P. gave an increment of 204 per cent. (c.f. 213 per cent. for N. alone) ; N.P.K an increment of 475 per cent. (c.f. 342 per cent. for N.K. alone).

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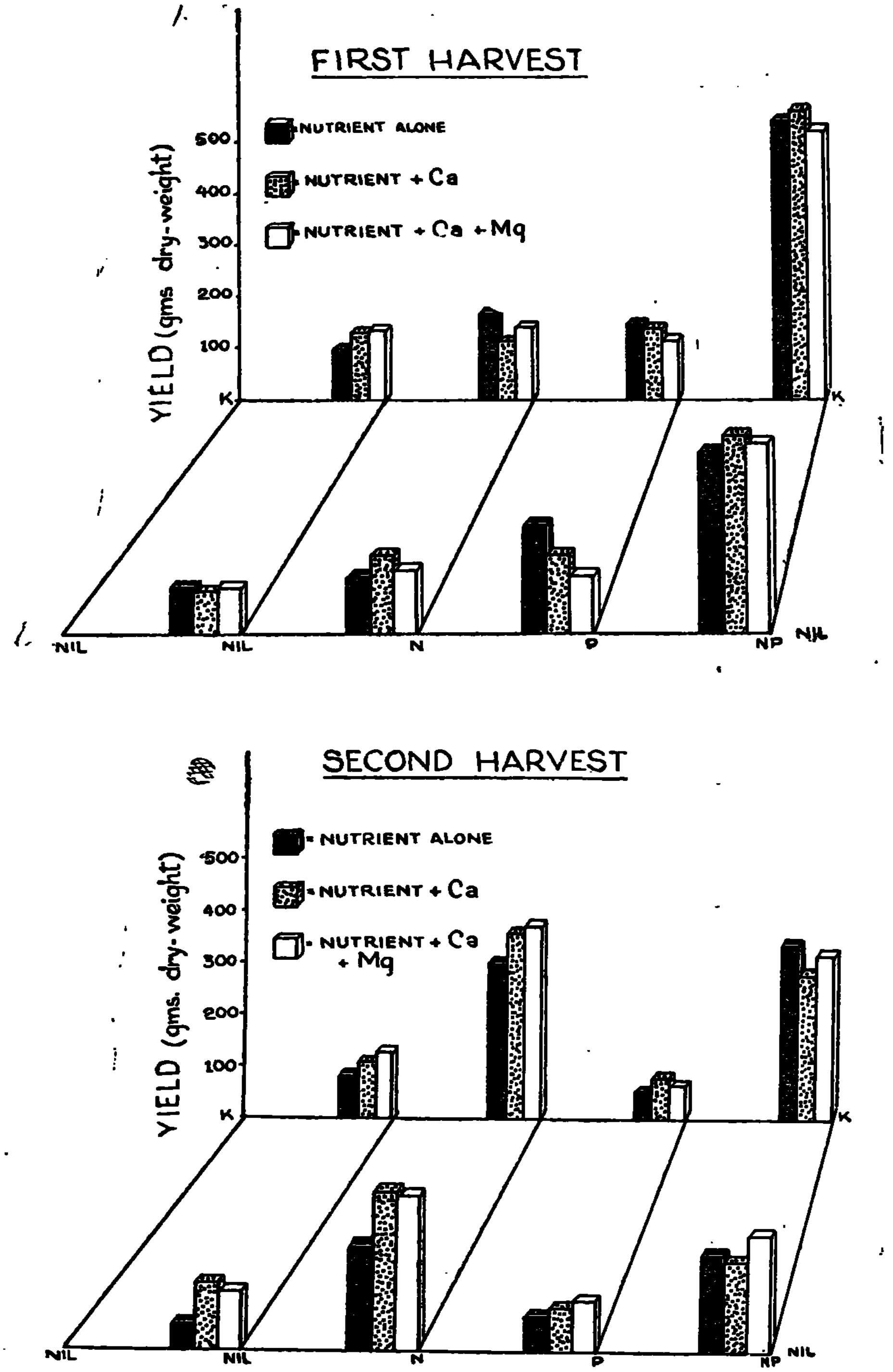
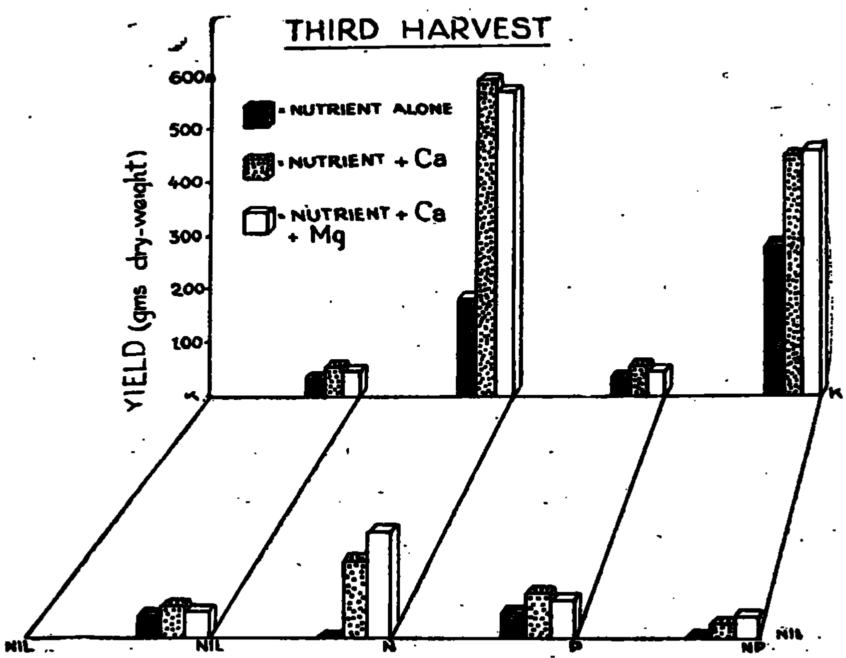
There was no significant improvement from the addition of Ca, but there was a small negative interaction between Ca. and P.

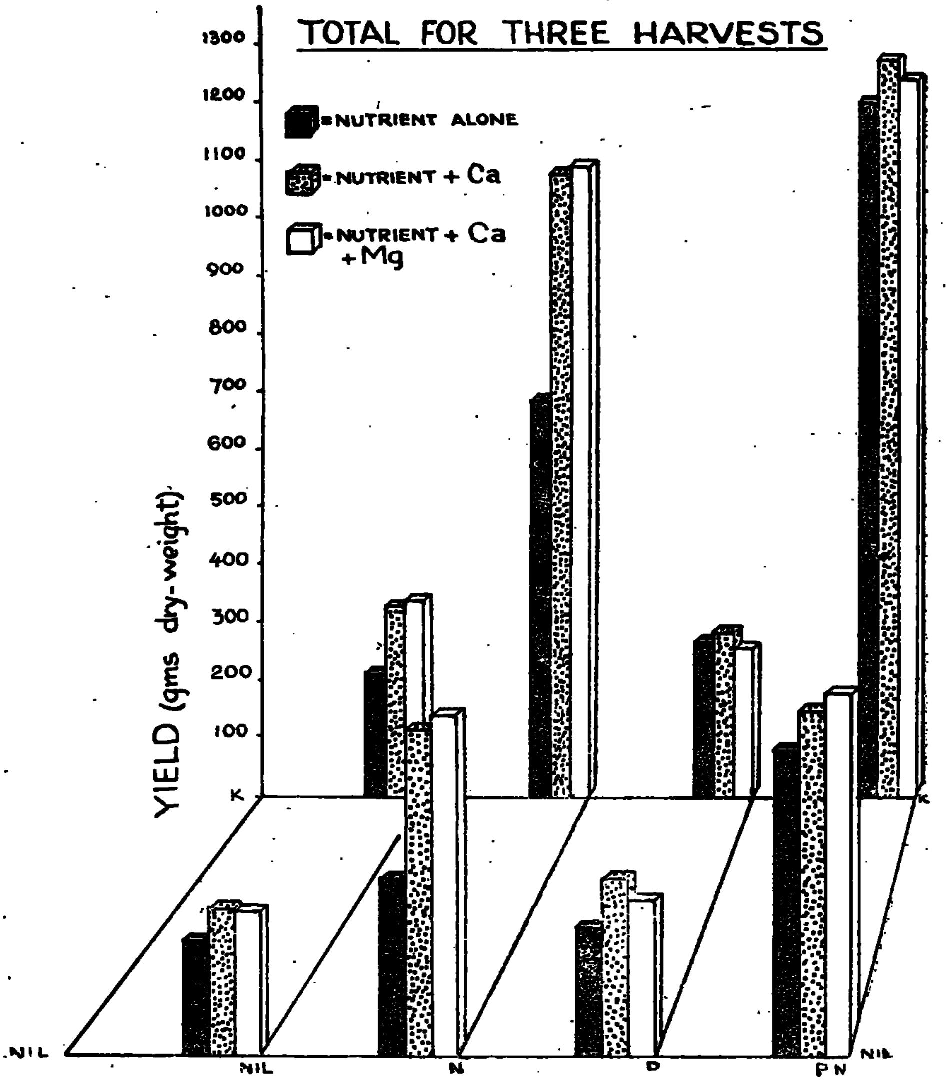
3rd Harvest. In the third harvest P. and K. alone or in combination, had no effect on yield. In presence of N. alone, three out of four plants died, and with N. P. alone, all plants died. N. K. gave an increment of 465 per cent., and N. P. K. an increment of 508 per cent.

Fig. 1.—*Experiment 1. Diagram showing mean yields for two replicates of all treatments in three successive harvests of* Paspalum commersonii.





(Below) Fig. 2.—*Experiment 1. Diagram showing Cumulative yields from three harvests of* Paspalum commersonii



In this harvest Ca. also had a very big effect, and N.Ca., N.K.Ca., and N.P.K.Ca., gave increments of 273 per cent, 1,321 per cent and 994 per cent., respectively.

B. Experiment 2

(i) **Objective.** To measure the effect of major nutrients (N. P. K. Ca. and Mg), and of " X " (a mixture of Cu, Zn, Mn, Fe, B and Mo), on the yield of *Paspalum commersonii* growing on " *Lateritic Sand* ".

(ii) **Design and Procedure.** The design of this experiment was identical with that of *Experiment 1* and all nutrients were applied in forms and doses enumerated in Table 1. The experiment was planted on January 22, 1957, and harvested four times, viz. :—on March 11, May 6, June 7 and July 8, 1957. Additional nutrients were applied as follows :—

On March 5, 1957— 2.5 cwt./acre $(NH_4)_2$ SO_4 were applied to all pots with added N. Total dose then ≡ 177 lb./acre of N.

On April 16, 1957— 4 cwt./acre NH_4NO_3 were applied to all pots with added N. Total dose then ≡ 335 lb./acre of N.

On May 10, 1957— 3 cwt./acre K_2SO_4 ; 3 cwt. Na H_2PO_4 $2H_2O$; and 17.5 lb /acre " X " were applied to all pots with added K. P. and X, respectively. Total dose then ≡

300 lb./acre of K.
134 lb./acre of P.
5.4 lb./acre of Cu.
5·2 lb./acre of Mn.
1.5 lb./acre of B.
0.8 lb./acre of Mo.

On June 7, 1957— 2 cwt./acre NH_4NO_3 were applied to all pots with added N. Total doe then ≡ 414 lb./acre of N.

(iii) **Results.** Cumulative yields from the four harvests, and from all treatments are recorded in Table III and in Figs. 3 and 4.

TABLE III.—*Experiment 2. Showing cumulative yields, and level of significance for all treatments affecting the yield of* Paspalum commersonii. *n.b. Significance at 5 per cent. recorded.*

Treatment				*Nil*	*Mg.*	*X*	*MgX*
nil	nil	nil	nil	2·24	2·94	3·75	2·86
			K.	2·53	2·86	2·59	3·29
nil		P.	nil	3·17	3·73	3·84	3·73
			K.	2·72	2·80	3·27	2·92
	N.	nil	nil	6·02	6·02	6·99	9·01
			K.	7·46	12·12	9·84	16·48
		P.	nil	3·72	3·78	8·44	7·70
			K.	6·84	5·64	12·15	9·33
Ca.	nil	nil	nil	2·72	4·31	3·63	3·86
			K.	4·40	4·00	3·68	3·61
		P.	nil	4·14	5·21	4·38	4·41
			K.	4·59	2·25	2·90	3·93
	N.	nil	nil	9·99	11·38	7·73	11·58
			K.	19·45	23·83	23·06	20·74
		P.	nil	7·57	8·34	6·95	8·32
			K.	30·03	29·51	32·27	33·22

Effective Treatments and Level of Significance	
K. (.1)	K.P.N. —
P. —	K.P.Ca. (1.0)
N. (.1)	K.P.H. —
Ca. (.1)	K.N.Ca. (.1)
Harv. (.1)	K.N.H. (.1)
K.P. —	K.Ca. H. (.1)
K. N. (.1)	P.N.Ca. (1.0)
K.Ca. (.1)	P.N.H. (1.0)
K.H. (.1)	P.Ca. H. (1.0)
P.N. —	N.Ca.H. (.1)
P.Ca. —	K.P.N.Ca. —
P.H. (1.0)	K.P.N.H. —
N.Ca. (.1)	K.P.Ca.H.(1.0)
N.H. (.1)	K.N.Ca.H. (.1)
Ca. H.(.1)	K.P.Ca.H. (.1)
	P.N.Ca. H. (.1)

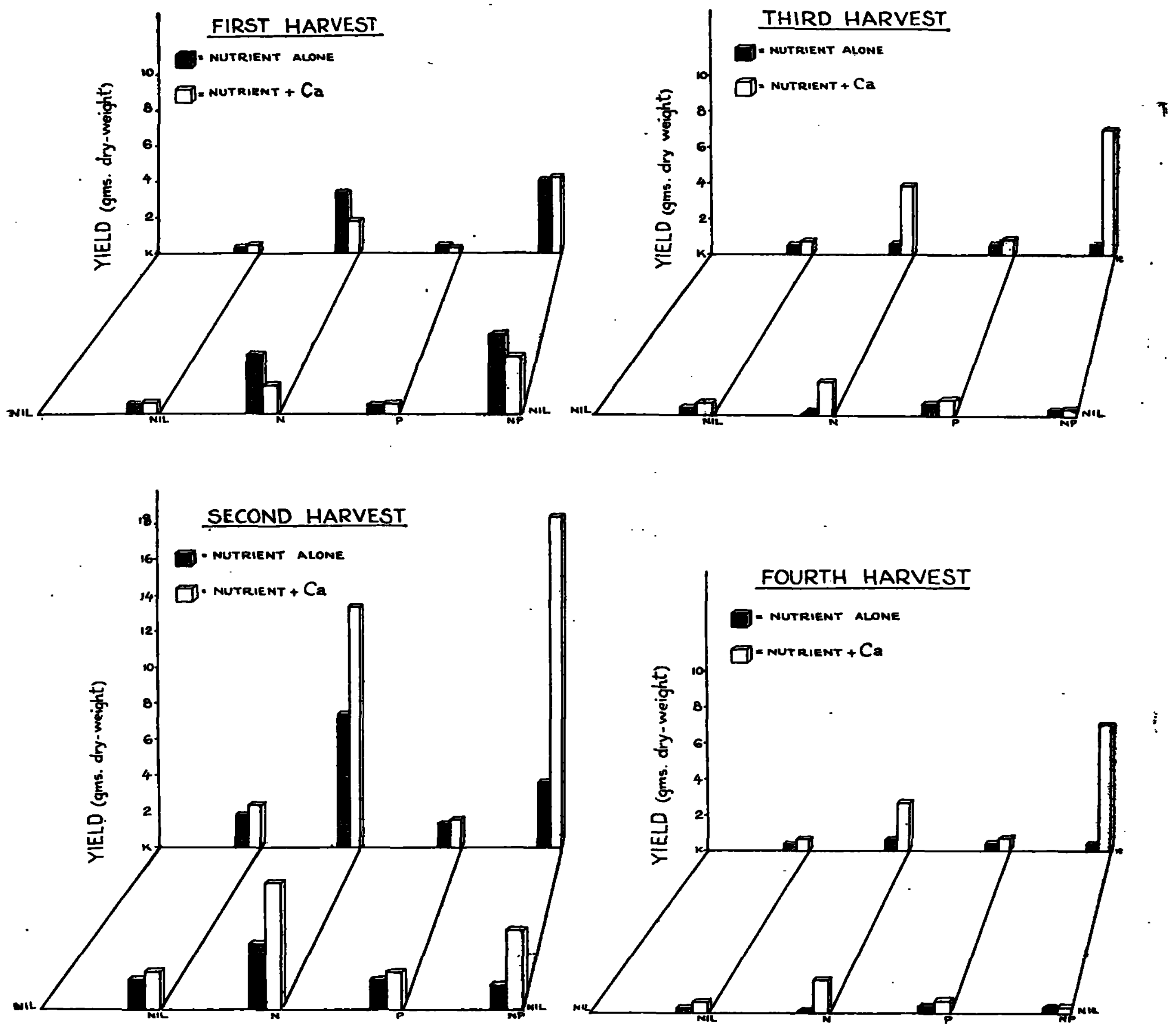


Fig. 3.—*Experiment 2. Diagram showing mean yields for two replicates of all effective treatments, in four successively harvests of* Paspalum commersonii.

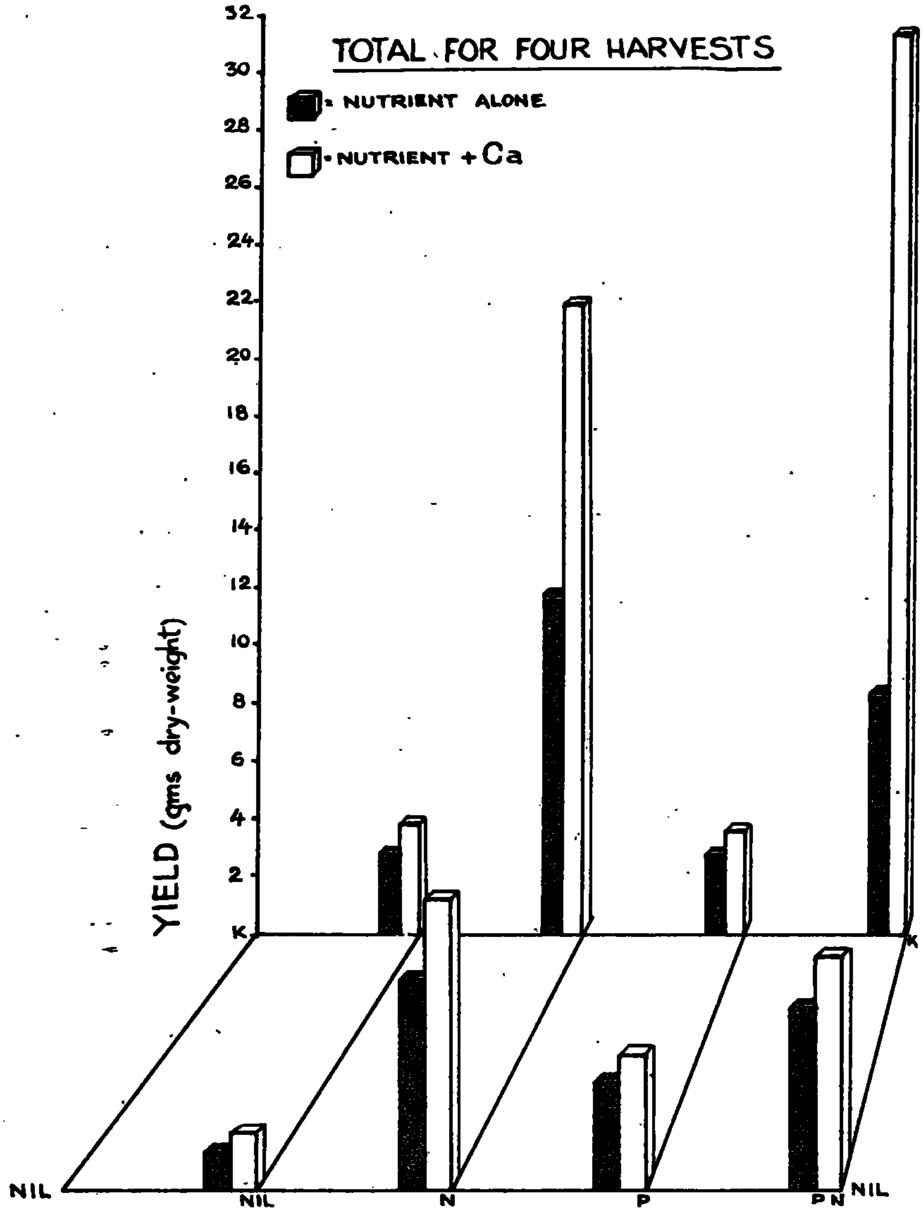


Fig. 4.—*Experiment 2. Diagram showing cumulative yields from four harvest of* Paspalum commersonii.

The data show that there was no significant response to Mg. in any harvest. In the first harvest there was a significant response to X (alone and in combination with N. and K.) which was consistent in four treatments, viz. :—

Treatment	*Effect of X*	*Level of Significance*
X. (alone)	+29%	1%
K. X.	+47%	5%
N.X.	+25%	1%
K.N.X.	+52%	5%

However, there was no effect from X in subsequent harvests and the data from four replicates (nil, Mg, X and MgX.) were therefore combined as a 2^4 factorial experiment with four replicates and mean yields for each harvest are recorded in Table IV.

TABLE IV.—*Experiment 2. Showing mean yields for four replicates (nil, Mg. × and Mg ×), and level of significance for all treatment 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. %*
1	nil	nil	0·45	3·17	0·49	4·42	P. (0·1) P.N. (0·1)
		K.	0·47	3·54	0·40	4·26	N. (0·1) N.Ca. (0·1)
Age 48 Days		nil	0·41	1·55	0·54	3·30	Ca. (1·0)
	Ca.	K.	0·56	1·86	0·39	4·24	
2		nil	1·67	3·82	1·89	1·47	K. (0·1) K.N. (0·1) K.N.Ca. (0·1)
	nil	K.	1·69	7·30	1·87	3·44	N. (0·1) K.Ca. (0·1) P.N.Ca. (1·0)
Age 104 Days		nil	2·10	6·91	2·28	4·39	Ca. (0·1) N.Ca. (0·1)
	Ca.	K.	2·32	13·38	1·96	18·43	
3		nil	0·46	0·01	0·67	0·01	K. (0·1) K.P. (1·0) K.P.N. (0·1)
	nil	K.	0·39	0·56	0·40	0·39	N. (0·1) K.N. (0·1) K.P.Ca. (0·1)
Age 136 Days		nil	0·54	1·54	0·75	0·11	Ca. (0·1) K.Ca. (0·1) K.N.Ca. (0·1) N.Ca. (0·1)
	Ca.	K.	0·58	3·70	0·57	6·74	
4		nil	0·35	0·00	0·56	0·00	K. (0·1) K.N. (0·1) K.N.Ca. (0·1)
	nil	K.	0·26	0·07	0·26	0·39	Ca. (0·1) K.Ca. (0·1)
Age 167 Days		nil	0·58	0·18	0·96	0·00	N.Ca. (0·1)
	Ca.	K.	0·53	2·82	0·50	1·86	

That data may be summarized as follows :—

1st Harvest. In the first harvest, P. and K. alone or in combination, had no effect on yield, but N. and N.K. gave increments of 602 per cent. and 687 per cent., respectively. N.P. and N.P.K. gave increments of 882 and 847 per cent., respectively.

Calcium was responsible for some depression in yield, and corresponding increments were :—N.Ca. 244 ; N.K.Ca. 313 ; N.P.Ca. 611, and N.P.K.Ca. 842 per cent. Only the N.P.K.Ca. treatment gave a yield comparable with that in absence of Ca.

2nd Harvest. In the second harvest, K. and P. alone or in combination, had no effect on yield ; N. and N.K. gave increments of 128 and 337 per cent., respectively, but in presence of P. they were reduced to 'nil' (N.P.) and 106 per cent. (N.P.K.).

Calcium alone, was responsible for some increase in yield (increment of 26 per cent.), and there was a progressive improvement, with increments of 314 per cent. (N. Ca.), 701 per cent. (N.K.Ca.), and 1,004 per cent. (N. P. K. Ca.). Any adverse effect from P. was restricted to one treatment (N.P.Ca.) :—increment of 163 per cent. (c.f.314 per cent. for N.Ca.).

3rd Harvest. In the third harvest, N.P. and K. all had only a very small effect on yield ; and it is a point of some importance that in absence of K. three out of the four plants in both N., and N. P. treatments died.

Calcium alone, gave a small increase in yield (increment of 17 per cent.) and in presence of Ca. there was again progressive improvement, with increments of 235 per cent. (N.Ca.), 704 per cent. (N.K.Ca.), and 1,387 per cent. (N.P.K.Ca.). Here again, P. in absence of K. was responsible for some depression in yield.

4th Harvest. In the fourth harvest, P. and K. alone, had very little effect on yield, and in the absence of K., all plants receiving N. and N.P. died. K.N. caused an appreciable decrease in yield (decrement of 80 per-cent.); K.P.N. had no significant effect.

Calcium alone, and in the presence of K., gave increments of 66 and 51 per cent. ; P.Ca. an increment of 174 per cent. In the Ca.N. treatments three out of four plants died, and with N.P.Ca. all plants died. N.K.Ca. gave an increment of 707 per cent., and N.P.K.Ca. a lesser increment of 431 per cent.

C. Discussion on Experiments 1 and 2

(i) **Interpretation of Results.** The data from these two experiments show that both "*Lateritic Loam*" and "*Lateritic Sand*" are deficient in N.P.K. and Ca. They also show that there was a changing pattern of responses in successive harvests, with increasingly acute deficiencies of N.K. and Ca., but with some apparent increase in the supply of available P.

These data do not present a clear picture of the extent (i.e. the full effect) of naturally occurring deficiencies, but the amount of growth in absence of any one nutrient can be computed as a *relative yield*, i.e. as a proportion of that when all nutrients were present, and available, in adequate supply, viz :—

$$\text{Relative Yield} = \frac{X}{A} \times 100$$

Where 'A' = yield with all nutrients in optimal supply, and 'X' = yield in absence of one, specified nutrient.

A *relative yield* would not be valid if there was any shortage in the supply or availability of nutrients in the complete fertilizer (A). Therefore in these experiments, if there was a big response to any nutrient, if there were deficiency symptoms, or if there was any other reason to suspect that the original dosage of any nutrient was sub-optimal; then more of that nutrient was added to the appropriate pots. That procedure carried with it some risk of over-dosage, but in that event—i.e. if there were adverse effects from overdosage, then *relative yields* would exceed 100 per cent., and appropriate adjustments could be made.

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 significant effect on yield) were separately computed. *Mean Relative Yields*, and standard deviations, were then calculated from those individual values. See Table V.

TABLE V.—*Showing calculation of mean relative yields and standard deviations for the third harvest of Experiment 1.*

Replicate	*YIELD IN GMS.*		*Relative Yield (-N)*	*Replicate*	*YIELD IN GMS.*		*Relative Yield (-P)*
	N.P.K.Ca.	*P.K.Ca.*			*N.P.K.Ca.*	*N.K.Ca.*	
1 (nil)	4·78	0·64	13	1 (nil)	4·78	5·57	117
2 (Mg)	4·03	0·33	8	2 (Mg)	4·03	6·31	132
3 (X)	4·13	0·51	12	3 (X)	4·13	5·79	140
4 (MgX)	4·78	0·44	9	4 (MgX)	4·78	5·35	112
Mean			10	Mean			125
s.d.			$\pm$ 1·2				$\pm$6.7

Replicate	*YIELD IN GMS.*		*Relative Yield (-K)*	*Replicate*	*YIELD IN GMS*		*Relative Yield (-Ca)*
	N.P.K.Ca.	*N.P.Ca.*			*N.P.K.Ca.*	*N.P.K.*	
1 (nil)	4·78	0·34	7	1 (nil)	4·78	3·21	46
2 (Mg)	4·03	0·04	1	2 (Mg)	4·03	3·07	76
3 (X)	4·13	0·35	8	3 (X)	4·13	2·92	71
4 (MgX)	4·78	0·21	4	4 (MgX)	4·78	1·65	35
Mean			5	Mean			57
s.d.			$\pm$1·6	s.d.			$\pm$9·8

(ii) Relative yields for 'Lateritic Loam'. Mean relative yields for *Experiment 1*, are shown diagrammatically in Figs. 5 and 6.

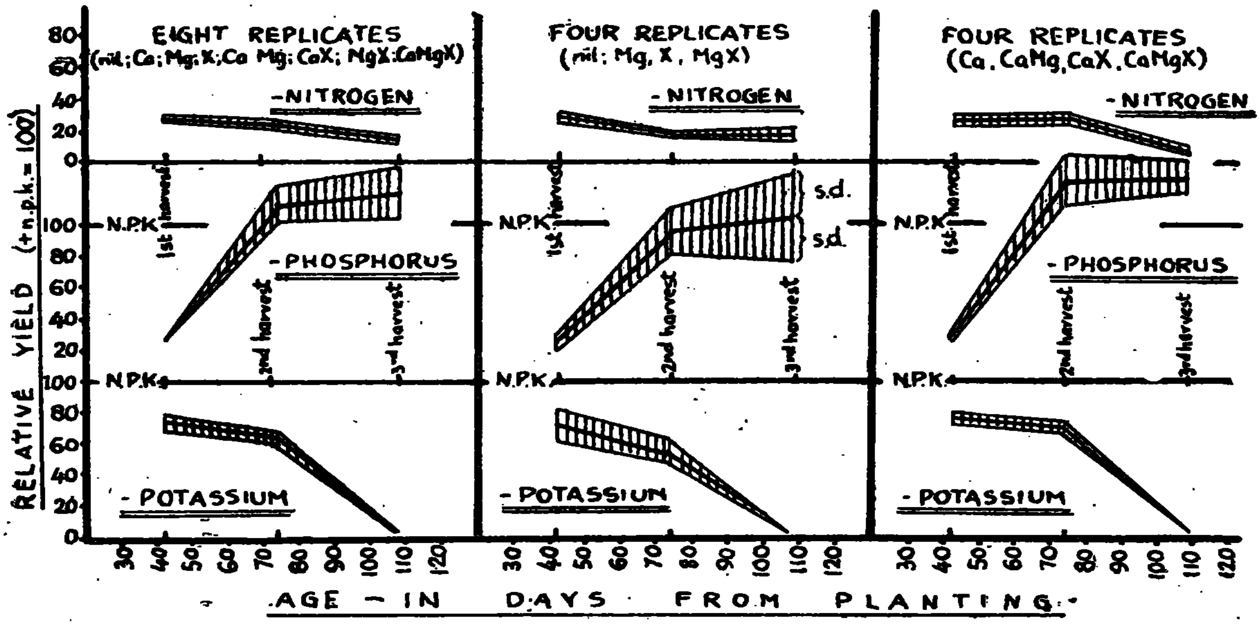


Fig. 5.—Experiment 1. Diagram showing mean relative yields (± standard deviation) for 'no phosphorus', 'no nitrogen' and 'no potassium', as calculated from 3 sets of replicates. (See Text).

In Fig. 5 only the effect of '–N', '–P' and '–K' are recorded but each has been calculated from 3 sets of data (i.e. using different replicates). The pattern of relative yields for '–N' and '–K' is essentially the same in all three diagrams, but there are some differences in the magnitude of relative yields for '–P' :— they can be interpreted as follows :—

(a) No Phosphorus. In all three diagrams there was at first an acute deficiency of P. (e.g. where Ca. had been applied relative yields for the first harvest did not exceed a mean value of $26 \pm 3 \cdot 1$), but in subsequent harvests—still without any application of phosphorus—relative yields rose steadily to equal, or exceed, that of plants receiving all three nutricients (N.P.K.).

A relative yield which is significantly greater than 100 is possible only if the particular nutrient is having an adverse effect on plant growth :—any toxic compound, for instance, would have that effect.

Too much of any nutrient could have the same effect, but only if all other nutrients were present, and available, in sufficient quantity. Under any other circumstances :—e.g. with incipient deficiency of N.K. or Ca.,—a second limiting factor would intrude, and relative yields could not exceed 100. For example, in this experiment and in absence of Ca. (calcium then being a second limiting factor) relative yields for '–P' did not exceed 100.

The data therefore show that in the second and third harvests of this experiment, the natural supply of available P. was near optimal, and application of 3 cwt./acre $NaH_2PO_4 2H_2O$ caused some depression in yield.

In all other respects this pattern of relative yields was essentially similar to that recorded from similar experiments with the '*Lateritic Gravel*' (see C.R.I. Bulletin 11), and subject to the same interpretation, viz :—'It must be assumed that available phosphate, which was originally in short supply, had increased; possibly as a result of chemical or biological changes in the soil'.

Finally in this experiment, any effect from excess P. on the complete fertilizer (N.P.K.Ca.) would be reflected in relative yields for '–N', '–K' and '–Ca.'. Therefore in the 2nd and 3rd harvests, relative yields for N, K and Ca. were re-calculated, on a basis of 100 for N.K.Ca. That data was used in compiling Fig. 6.

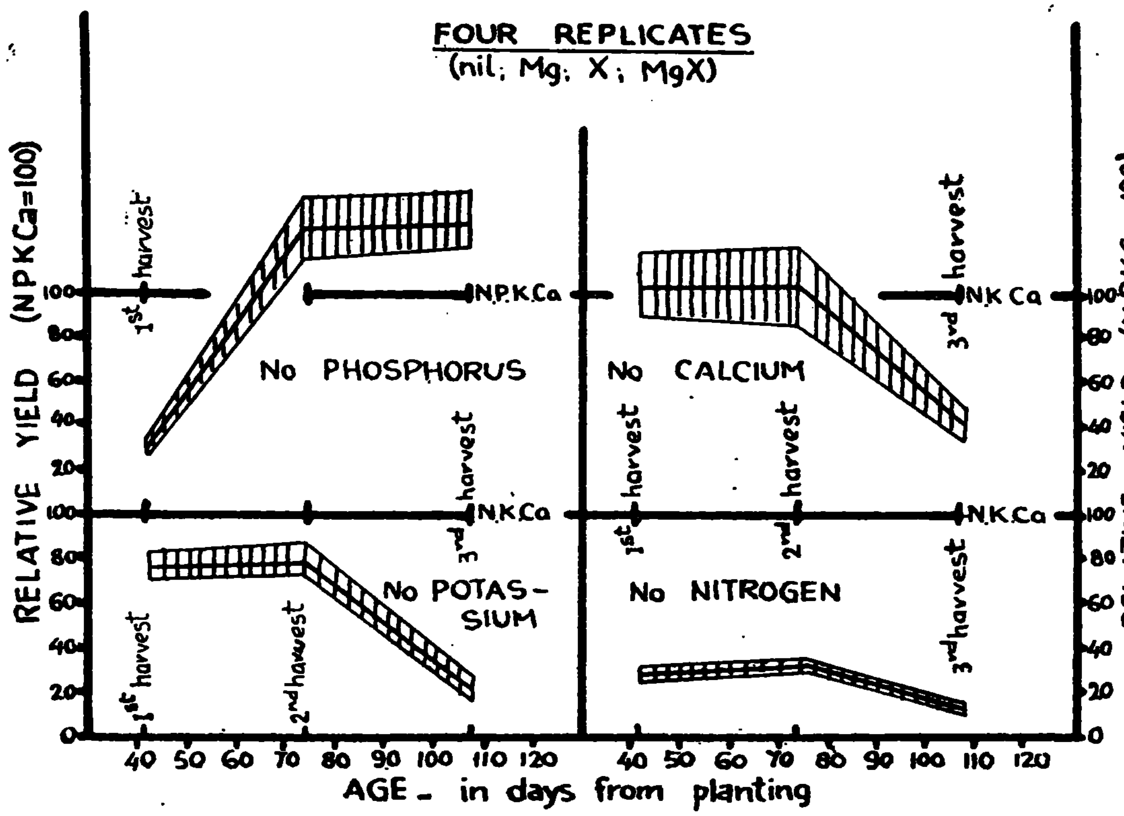


Fig. 6.—*Experiment 1. Diagram showing mean relative yields (± standard deviation), and progressive effects from absence of N. P. K. and Ca, in the 'Lateritic Loam.'*

(b) **No Nitrogen.** Nitrogen was at all times an important limiting factor in plant growth, and relative yields decreased from an initial value of $26 \pm 3 \cdot 1$ to a final value of $10 \pm 1 \cdot 2$. In other words, the experiment has shown that without some application of nitrogen, no amount of fertilizers will give yields exceeding 1/4 to 1/8 the potential level of production on this soil.

(c) **No Potassium.** In the absence of potassium relative yields decreased steadily from an initial value of $76 \pm 3 \cdot 4$ to final values of $20 \pm 5 \cdot 9$. They did not tend towards an asymptote, and all K_0 plants eventually died. As with the '*Lateritic Gravel*', these data suggest that there had been a gradual fixation of available K.

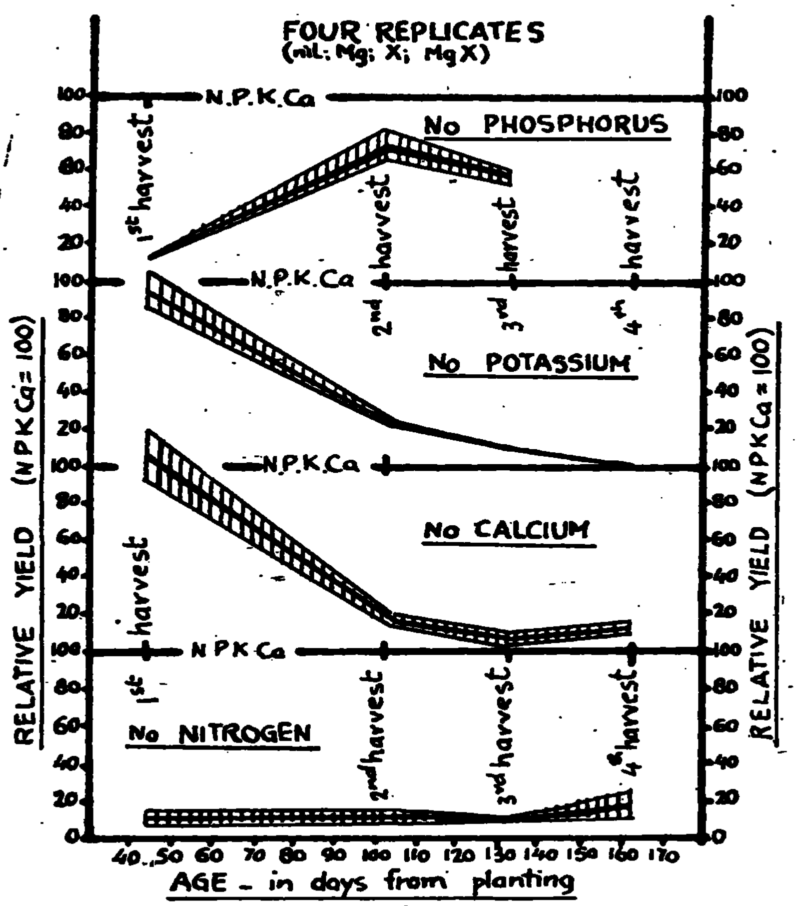


Fig. 7.—*Experiment 2. Diagram showing mean relative yields* ($\pm$ *standard deviation), and progressive effects, from absence, of N.P.K. and Ca, in* '*Lateritic Sand*'

d) **No Calcium.** In the absence of calcium relatively yields decreased steadily from a mean value of $104 \pm 13 \cdot 4$ in the first harvest, and $102 \pm 17 \cdot 1$ in the second harvest, to $40 \pm 7 \cdot 2$ in the third harvest. Initially, i.e. prior to the first harvest, there was visual evidence of some depression from Ca., but that effect was short-lived.

(iii) **Relative Yields for the 'Lateritic Sand'.** In *Experiment 2* relative yields were calculated on a basis of N.P.K.Ca.=100 ; and the data for each of the first three harvests are shown diagrammatically in Fig. 7. In the fourth harvest there was again some complication from excess P. and relative yields for '–N', '–K' and '–Ca.' were calculated on a basis of N.K.Ca.=100.

(*a*) **No Phosphorus.** In absence of P., relative yields rose sharply from $11 \pm 1 \cdot 2$ in the first harvest, to an over-all mean value of $64 \pm 5 \cdot 8$ for the second and third harvests. In the fourth harvest there was a very big increase to $151 \pm 25 \cdot 4$.

As in *Experiment* 1, a relative yield exceeding 100 could not be reconciled with any deficiency of N.K. or Ca. in the complete fertilizer, and the very high values—which were recorded in all four replicates of the fourth harvest—must be interpreted as showing excess P. in the complete fertilizer (N.P.K.Ca.). Moreover in this experiment that effect would be aggravated by the addition of more $NaH_2PO_42H_2O$ on 10th May. Those artificially inflated values were not incorporated in Fig. 7.

For that harvest (No. 4), mean relative yields for '–N', '–K' and '–Ca' were re-calculated, on a basis of 100 for N.K.Ca. and those values were used in completing Fig. 7.

(*b*) **No Nitrogen.** In absence of N., and in the first three harvests, relative yields were consistently low (over-all mean value of 10 ± 1·2). In the fourth harvest they were some what higher (18 ± 8), but not significantly greater than the over-all mean for the first three harvests. Prior to the first harvest there was visual evidence of still better growth, but that effect was very short lived and it did not affect yields for the first harvest.

(*c*) **No Potassium.** In absence of K. and in the first three harvests, relative yields decreased steadily from an initial value of 95 ± 9·8 (first harvest), through 24 ± 1·0 (second harvest) to 9 ± 1·3 (third harvest). The decline however, was some what less rapid than in other soils and there was a reversed inflection suggesting some loss of any capacity for K- fixation in this soil. In the fourth harvest, all K_0 plants were dead.

(*d*) **No Calcium.** In absence of Ca., relative yields declined rapidly from an initial value of 105 ± 14·5 for the first harvest to 18 ± 3·0 and 6 ± 3·6 in the second and third harvests respectively. In the fourth harvest, two out of the four Ca_0 plants were dead, and the mean relative yield (c.f. N. K. Ca. =100) was 14 ± 2.

D. Experiment 3

(i) Objective. To measure the effect of sulphur on the yield of two species growing on '*Lateritic Loam*'.

(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. K_2SO_4 ; $(NH_4)_2SO_4$; $MgSO_4$; $CaSO_4$; H_2SO_4 ;and S_4) and five with no sulphur (i.e. KCl ; NH_4 NO_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 NaH_2 $PO_4 \cdot 2$ H_2O). The basic treatment was S_4.(0·175 gms./pot ≡ 123 lb./acre of S.). The *Paspalum* was planted on 15th and the *Phaseolus* on 28th May, 1957. Both species were harvested once, viz :—the *Paspalum* on July 17, the *Phaseolus* on July 23, 1957.

(iii) Results. Individual yields are recorded in Table VI.

TABLE VI—*Experiment 3.* . *Showing individual and mean yields for two treatments.*

Species	*Treatment*	$(NH_4)_2SO_4$ NH_4NO_3	$MgSO_4$ $MgCl_2$	$CaSO_4$ $CaCO_3$	H_2SO_4 HCl	S_4 *Nil*	*Total*
Paspalum	nil	3·45	1·45	0·51	2·14	1·68	9·23
	S	2·02	2·34	2·17	1·85	1·41	9·79
Phaseolus	nil	0·98	0·57	1·21	1·26	1·51	5·53
	S	0·50	1·13	0·62	1·06	1·14	4·45
Mean	nil	2·21	1·01	0·86	1·70	1·59	7·37
	S	1·26	1·73	1·39	1·45	1·27	7·10

Sulphur had no effect on the yield of either species.

E. Experiment 4

(i) **Objective.**—To measure the effect of sulphur on the yield of two species growing on '*Lateritic Sand*'.

(ii) **Design and Procedure.** The design of this experiment was identical with that for *Experiment* 3, and the same two species (*Paspalum commersonii* and *Phaseolus lathyroides*) were grown. The *Paspalum* was planted on 15th and the *Phaseolus on* 28th May, 1957. They were harvested once, on 17th and 28th July, 1957, respectively.

In the original design for *Experiments 3 and 4* one more comparison viz :—K_2SO_4 *vs* KCl was included. However in both experiments, and in similar experiments with other soils, the K_2SO_4 treatment was—in all cases—outstanding (e.g. in these two experiments, yields of 10.99 and 10.11 were recorded); no explanation is available, but in view of that general result, the K_2SO_4, and KCl yields were not included in the data for these two experiments.

(iii) **Results.** Individual yields are recorded in Table VII.

TABLE VII—*Experiment 4. Showing individual and mean yields for two treatments*

Species	*Treatment*	*$(NH_4)_2SO_4$* *NH_4NO_3*	*$MgSO_4$* *$MgCl_2$*	*$CaSO_4$* *$CaCO_3$*	*H_2SO_4* *HCl*	*S_4* *Nil*	*Total*
Paspalum	nil	0·78	2·15	0·77	0·96	0·27	4·93
	S	4·15	3·41	3·42	4·11	5·38	20·83
Phaseolus	nil	0·55	0·33	1·02	0·97	0·56	3·43
	S	0·72	0·72	0·94	0·85	0·84	4·07

In this experiment, *Phaseolus lathyroides* made very unhealthy growth, and all plants were infected by virus, and by a species of fungus which grew on the leaves :—There were no significant differences between treatments. Plants of *Paspalum commersonii* grew well, and they showed a marked response to sulphur :—which gave a mean increment of 620 per cent.

The data therefore show that plants growing on the "*Lateritic Sand*" would suffer from a deficiency of sulphur. In "*Lateritic Loam*" (and in "*Lateritic Gravel*") there was no evidence ot sulphur deficiency.

F. Experiment 5

(i) **Objective.** To measure any effect from increasing dosage of boron and of calcium on the yield of *Phaseolus lathyroides* growing on two soils ("*Lateritic Loam*" and "*Lateritic Sand*").

(ii) **Design and Procedure.** This was a 4 × 3 × 2 factorial experiment with one replicate of each treatment. All pots were given a basal dressing of N, P, K, Mg, Fe, Cu, Mn, Zn, and Mo. The N. was applied as NH_4NO_3, (3 cwt./acre) ; K. as K_2SO_4, (4½ cwt./acre) ; all others in forms and doses enumerated in Table I. There were three levels of calcium :—0, 10 and 20 cwt./acre $CaCO_3$, and four levels of boron :—0, 3, 6 and 9 lb./acre of $Na_2B_4O_7.10H_2O$.

For this experiment, and in order to avoid boron contamination (i.e., from "Pyrex glassware"), all water was finally distilled in chromiumplated copper apparatus.

The *Phaseolus* was planted on 12th May, 1957, and harvested twice, viz. :—on June 28, and July 23, 1957. All plants were grown from seed, and all seedlings in excess of two, uniform plants per pot were removed as they appeared.

On 10th June, 1957, that number was reduced to one plant per pot, and the "thinnings" were weighed, to give some additional data.

(iii) **Results.** Individual yields for "thinnings", and for two harvests are recorded in Talbe VIII.

TABLE VIII—*Experiment 5. Showing individual yields, and level of Significance for all treatments affecting the yield of* Phaseolus lathyroides

Soil	*Harvest*	*Treat-ment*	B_0	B_3	B_6	B_9	*Effective Treatment*	*Level of Signifi-cance*
LOAM	Thinnings Age 29 Days	Ca_0	0·14	0·23	0·18	0·16	B. (—)	5·0
		Ca_{10}	0·14	0·22	0·14	0·14	Harvest	0·1
		Ca_{20}	0·14	0·16	0·20	0·14	Soil	5·0
							B. Harv.	5·0
	(1) Age 47 Days	Ca_0	3·43	2·52	1·78	2·50	Har. Soil	0·1
		Ca_{10}	2·78	2·44	1·36	2·32	B.Har.Soil	5·0
		Ca_{20}	2·98	2·45	2·62	2·25		
	(2) Age 72 Days	Ca_0	0·91	1·06	1·19	0·85		
		Ca_{10}	1·19	1·21	1·25	1·16		
		Ca_{20}	1·09	1·20	0·73	0·95		
SAND	Thinnings Age 29 Days	Ca_0	0·03	0·07	0·04	0·03		
		Ca_{10}	0·04	0·05	0·04	0·03		
		Ca_{20}	0·02	0·06	0·07	0·08		
	(1) Age 47 Days	Ca_0	1·05	1·10	1·09	0·45		
		Ca_{10}	1·34	0·83	1·44	0·55		
		Ca_{20}	0·70	1·22	0·92	0·35		
	(2) Age 72 Days	Ca_0	1·29	0·98	0·69	1·06		
		Ca_{10}	1·42	1·08	1·09	0·92		
		Ca_{20}	1·49	1·45	1·19	1·23		
	MEAN		1·12	1·02	0·89	0·84		

In both of these soils boron was responsible for some depression in yield. That effect was small, but progressive (decrements of 10, 20 and 25 per cent. for B_3, B_6 and B_9, respectively). It was significant at the five per cent level

G. Experiment 6

(i) **Objective.** To measure the effect of minor nutrients on the yield of *Paspalum commersonii*, grown on "*Lateritic Sand*".

(ii) **Design and Procedure.** This was a 2^5 factorial experiment using four nutrients (Fe, Cu, Mn and Zn), and two replicates of each treatment. All pots were given a basal dressing of N, P, K, Ca, Mg and B. Calcium (10 cwt./acre $CaCO_3$) was mixed with the upper 1½ inches of soil ; all other nutrients were applied in solution.

Nitrogen was applied as NH_4NO_3 (3 cwt./acre), K as K_2SO_4 (4½ cwt./acre) ; all other nutrients in forms and doses enumerated in Table I. The experiment was planted on 12th May, 1957, and harvested twice, i.e. on 26th June, and 17th July, 1957. All plants were grown from seed, and seedlings in excess of two uniform plants per pot were removed as they appeared. On 10th June, this number was reduced to one plant per pot, and the " thinnings ", were weighed to provide some additional data.

(iii) **Results.** Total yields for two replicates are rocorded in Table IX.

TABLE IX—*Experiment 6. Showing total yields from two replicates, and level of significance for all treatments affecting the yield of* Paspalum commersonii. *n.b. Significance at 5 per cent. not recorded.*

Harvest	*Treatment*		*Nil*	*Mn.*	*Zn.*	*Mn. Zn.*	*Effective Treatment*	*Level of Significance per cent.*
Thinnings	nil	nil	0·23	0·25	0·25	0·23	Cu.	0·1
		Cu.	0·22	0·26	0·13	0·25	Harvest	0·1
Age 29 Days	Fe.	nil	0·28	0·24	0·21	0·27	Cu. Fe.	1·0
		Cu.	0·23	0·27	0·24	0·19	Cu. Harv.	1·0
(1)	nil	nil	3·49	3·67	4·08	4·27		
		Cu.	3·99	3·95	3·51	3·42		
Age 45 Days	Fe.	nil	3·94	3·95	3·74	3·26		
		Cu.	4·06	5·05	5·40	4·56		
(2)	nil	nil	3·10	3·46	3·83	3·29		
		Cu.	3·69	4·70	3·88	4·46		
Age 66 Days	Fe.	nil	3·36	2·55	3·42	3·00		
		Cu.	4·09	5·22	4·48	5·88		

The data showed that there was no effect from zinc, or manganese, in any harvest ; but in the first harvest copper and iron—together, were responsible for some increase in yield (mean increment of 35 per cent.). In the second harvest, copper alone gave a mean increment of 45 per cent., and there was no effect from iron. In " thinnings " there was no effect from any of the minor elements.

The data therefore show that in the early stages of growth (i.e. at ages of 45 and 66 days) there was a small but significant deficiency of copper and a transitory effect from iron. In *Experiment 1,* those effects were shortlived, and it is unlikely that any addition of trace elements would be economically worth-while at the present time.

However, the supply of available copper and of iron was barely sufficient, and might, in time, become more acute. Some further experiments with high-yielding crops, or pasture, are therefore desirable.

3. SUMMARY AND CONCLUSIONS

1. The data from six experiments with "*Lateritic Loam*" and "*Lateritic Sand*" have shown that these two soils are both deficient in nitrogen, potassium, and calcium. Both have shown an initial deficiency of phosphorus and a common tendency towards increasing supply of naturally occurring available phosphorus in later harvests of *Paspalum commersonii.* Only the "*Lateritic Sand*" has shown a deficiency of sulphur.

2. In the "*Lateritic Sand*" there was a small response to copper and some suggestion of an "incipient deficiency" of iron during the early stages of growth. However, that effect was short-lived, and application of trace elements is not likely to be economically worth-while at present. Some further experiments with high-yielding crops, or pasture, are desirable.

3. The data from these experiments, and from similar experiments with the "*Lateritic Gravel*" on Bandirippuwa Estate, have shown that the three soils are essentially similar in their nutrient status. This similarity was evident from a changing pattern of *relative yields,* which was common to all three soils.

4. The pattern of responses in "*Lateritic Gravel*" "*Lateritic Loam,*" and "*Lateritic Sand*"—in that order—showed some important differences in the magnitude of relative yields, together with a progressive deficiency of calcium. There was also some suggestion of a *decreasing capacity* for K.-fixation. All three soils showed an acute deficiency of nitrogen :—which is not a mineral nutrient.

5. In the "*Lateritic Gravel*", relative yields for the P_0 treatments rose to a maximum value of 70 ; calcium deficiency was not apparent until the fourth harvest (i.e. after 150 days) ; and relative yields for the K_0 treatments fell sharply to zero at 150 days.

6. In "*Lateritic Loam*" relative yields for the P_0 treatments rose to a maximum value of 125 ; calcium deficiency was evident after the second harvest (i.e. after 100 days) ; and relative yields for the K_0 treatments held at more than 75 for approximately 81 days.

7. In "*Lateritic Sand*" relative yields for the P_0 treatments did not exceed a mean value of $64 \pm 5{\cdot}8$ for the second and third harvests, but there was evidence of further improvement in the fourth harvest ; calcium deficiency was evident after the first harvest (i.e. after only 50 days). Relative yields

for the K_0 treatments fell less rapidly, and there was evidence of a decreasing capacity for K.-fixation.

8. Assuming that all three soils are derived from the one, or similar, parent material, it would appear that the "*Lateritic Loam*" represents the highest stage of development (i.e. the most fertile soil), and the "*Lateritic Sand*" a leached, or degraded derivative therefrom.

9. If that is so, and in view of current observation that this soil is highly erodible, then a first consideration in estate management—on these soils—should be to retain that soil above the "*Lateritic Gravel*", and on the relatively high ground where it is formed. The construction and maintenance of properly designed contour banks, provision of adequate ground cover, and indeed all forms of soil conservation and erosion control would seem to be fundamental requirements and essential to any form of good management.

10. From the national view point this is even more important; since the data from these experiments suggest that erosion and transportation of that soil to the valley floors is followed by severe leaching and loss of very great natural resources.

11. Adequate control of erosion would also have an appreciable effect on fertilizer requirements for "*Lateritic Gravel*" and "*Lateritic Loam*"; since the two soils require differing amounts of P. and K., and correct dosage would vary according to the amount of loam retained or lost by erosion.

12. While no precise recommendation is possible at this stage, it can be said that both soils would benefit from some addition of calcium (tentatively 5-10 cwt./acre $CaCO_3$). Application of potassium ($4\frac{1}{2}$ cwt./acre K_2SO_4) is likely to have markedly beneficial effects, but the optimum dosage is subject to considerable reduction where cultivation and aeration is practicable.

Both soils would benefit from an initial dressing of phosphate (equivalent to 80 lb. P_2O_5/acre), but there is a very real danger of over-dosage from repeated applications.

13. Both soils show an acute deficiency of nitrogen, and use of green manures, and/or application of frequent, small doses of nitrogenous fertilizers ($(NH_4)_2SO_4$ or NH_4NO_3) can be recommended.

14. The nutrient status of "*Lateritic Sand*" is very similar to that of the "*Cinnamon Sand*" and pending results from some further experiments, the same type of fertilizer mixture is recommended. Boron—which is incorporated in that mixture—need not be applied.

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