EFFECT OF LIMING AND HIGH PHOSPHATE APPLICATION ON PLANT GROWTH ON SOME NATAL OXISOLS

(Met opsomming in Afrikaans)

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Abstract

A number of pot experiments with Trudan *(Sorghum sudanense)* and lucerne *(Medicago sativa L.)* as test crops were conducted on soils representative of the Hutton, Farmhill and Balmoral series to study the response to lime (4 levels), Slagment (4 levels) and phosphorus (5 levels).

Lime requirement based on exchangeable aluminium index was sufficient to obtain maximum yield of Trudan while lucerne required a somewhat higher level of lime. Liming to pH 6,4 (SMP) had a depressive effect on the yield of both crops due to suspected decreased phosphorus availability.

Maximum response of Trudan to phosphate was obtained at 900, 500 and 300 ppm added P for the Farmhill, Hutton and Balmoral soils respectively while even larger amounts were required for lucerne. These results focus attention on the high phosphorus-fixation capacity of these soils and on the inability of lime to remedy this to any great extent.

Introduction

The main factor limiting crop growth in soils of the Highland Sourveld of Natal is their low plant-nutrient status (Van der Eyk, MacVicar & De Villiers, 1969).

As a result of the high rainfall in this area (900-1 100 mm annually), and the good physical condition of these soils, the profile has been impoverished by leaching. The acidity and low base status is usually associated with toxic levels of exchangeable aluminium (Reeve, 1970). Both exchangeable Al and Ca can be brought to an acceptable level by liming to pH 4,8 (0,01 M $CaCl_2$) or to pH 5,5 (water) (Hutchinson & Hunter, 1970; Sumner, 1970). Once satisfactorily limed, the productivity of these soils can be raised to a very high level by suitable fertilization although phosphorus availability remains a problem. If on the other hand excessive lime is applied, P-availability and yield are depressed.

It has been shown that the P-status of latisols with high P-sorbing capacity can be raised for a period of 9 years by heavy initial phosphate dressings (Fox, Plucknett & Whitney, 1968).

Anions which effectively complete for P-adsorption sites may result in improved P-availability (Deb & Datta, 1967; Easton, 1969). Increased yields caused by the addition of competing anions are however often equally well explained by decreased Al toxicity or in the case of SiO_2 by an increased SiO_2 nutrition (Raupach & Piper, 1959; Reeve, 1970).

The purpose of this paper is to investigate the effect of phosphate and two kinds of liming material on the yield of lucerne and Trudan grown on some Natal Oxisols.

Materials and methods

Some selected properties of the three soils studied are presented in Table 1.

Experiment 1 — In a 5 x 4 x 2 factorial experiment with three replications the response of Trudan *(Sorghum sudanense)* to phosphorus (5 levels) and liming (4 levels) with two qualities of lime was studied.

TABLE 1 Some selected properties of the experimental soils (After Reeve, (1970))

Soil	CEC	Ca	Mg	K	Na	Al	Mn	C	Clay	pH		PDI**
	me/100 g						ppm	%		Ca Cl₂*	H_2O	
Balmoral	5,3	1,7	1,6	0,2	0,1	1,4	31,2	1,9	37,0	4,7	5,3	0,390
Farmhill	5,6	2,2	1,3	0,7	0,1	0,4	10,4	4,2	57,9	4,6	5,4	0,070
Hutton	6,0	1,0	0,9	0,6	0,1	2,7	7,0	4,1	41,6	4,7	5,3	0,163

*0,002 M $CaCl_2$

**Phosphorus desorption index. This parameter measures the relative ease of desorption by Bray No 2 extractant (Reeve, 1970)

Phosphorus was added as finely-powdered single superphosphate (8,3% P) at the following levels: 100, 300, 500, 700 and 900 ppm P. Two qualities of lime were used viz A R $Ca(OH)_2$ (L), and Slagment (S). The composition of the latter is presented in Table 3. The neutralizing power of each was measured and the dressings were given in equivalent amounts calculated as $CaCO_3$ (Table 2). All pots received a basic dressing of N, K and micronutrients as indicated in Table 4.

TABLE 2 Levels of lime applied

Soil	Level of Lime		
	1*	2**	3***
	t $CaCO_3$/ha		
Balmoral	1,0	8,6	16,1
Farmhill	0,8	6,9	12,8
Hutton	4,6	13,0	21,5

*Based on Reeve's (1970) EAI method.
**Arithmetic mean of levels 1 and 3.
***SMP lime requirement to pH 6,4. (Shoemaker, McLean & Pratt, 1961).

TABLE 3 Composition of Slagment

Component	CaO	CaS	MgO	SiO_2	Al_2O_3	P_2O_5
%	35	3	12	33,5	13,5	0,05

TABLE 4 Nutrients added in pot experiment

Nutrient	N	K	Mg	S	Zn	Cu	B	Mn	Mo
mg/pot	250	310	48	64	3	3	1	1	1

The pH was measured in 0,01 M $CaCl_2$ using a 1:2,5 soil: solution ratio.

Experiment 2 — In a 5 x 4 unreplicated factorial experiment the response of lucerne to phosphorus (5 levels) and lime (4 levels) was studied. The same levels of phosphorus and $Ca(OH)_2$ and the same experimental technique as in experiment 1 were used. In the basal dressing (Table 5) nitrogen was omitted. The soil near the seeds was inoculated with an effective strain of rhizobia. The first cut was taken after five weeks and two further cuts at four-weekly intervals. With the exception of N, nutrients were reapplied after each cutting (Table 5). After the last cut the roots were removed from the soil and the effectiveness of the nodules was rated by estimating the number, volume and distribution of the nodules.* The tops and the roots were dried and their weight recorded.

Results

Experiment 1 — For the Balmoral and Hutton soils the response to liming is quadratic ($p = 0.1$) while for the Farmhill soil a slight overall linear depressive effect is obtained (Figure 1). For the former soils the first level of lime is sufficient to neutralise exchangeable Al and gives a yield close to the maximum. This initial response to lime decreases with increasing P levels because P is a very effective neutralizer of labile Al. The second level of lime did not significantly increase yield while the third level equivalent to the lime requirement by the SMP method to pH 6,4 (Shoemaker, McLean & Pratt 1961) significantly reduced yield.

*The help of Mr R S Marr is kindly acknowledged for performing the effectiveness rating of the nodules.

The magnitude of the response to liming is closely related to the level of exchangeable Al (Table 1).

The analysis of variance (not presented) indicates a highly significant linear, quadratic and cubic effect of P on yield. (Figure 2). The maximum response to P is obtained at 300 ppm for the Balmoral, 500 ppm for the Hutton and 900 ppm for the Farmhill soils. This response to P is adequately predicted by the PDI values presented in Table 1. The interaction of P and lime was not significant.

There is little difference in the effectiveness of the two liming materials although the Slagment appears to react somewhat more slowly and produces a more drastic yield reduction at high levels. The reason for the latter effect is not clearly understood at this stage but it is possible that some impurity in the Slagment might reach toxic levels with increased rates of application.

Experiment 2 — Because germination on soil of the Balmoral series was poor due to soil crusting, the results are not presented.

TABLE 5 Effect of lime and phosphate applications on the total yield of lucerne (three cuts) in grams dry matter per pot

Soil	Hutton					Farmhill				
Treatment	L0	L1	L2	L3	Total	L0	L1	L2	L3	Total
P1	1,53	4,24	4,78	0,58	11,13	0,90	2,53	3,47	1,76	8,66
P2	3,22	5,51	9,63	2,19	20,55	3,39	5,56	6,15	5,70	20,80
P3	5,57	7,69	11,83	4,69	29,78	5,27	6,78	7,68	6,29	26,02
P4	6,81	8,29	11,67	8,62	35,39	4,41	6,65	7,44	7,76	26,26
P5	7,54	8,84	13,20	10,83	40,41	5,68	7,88	8,01	7,63	29,20
Total	24,67	34,57	51,11	26,91	137,26	19,65	29,40	32,75	29,14	110,94

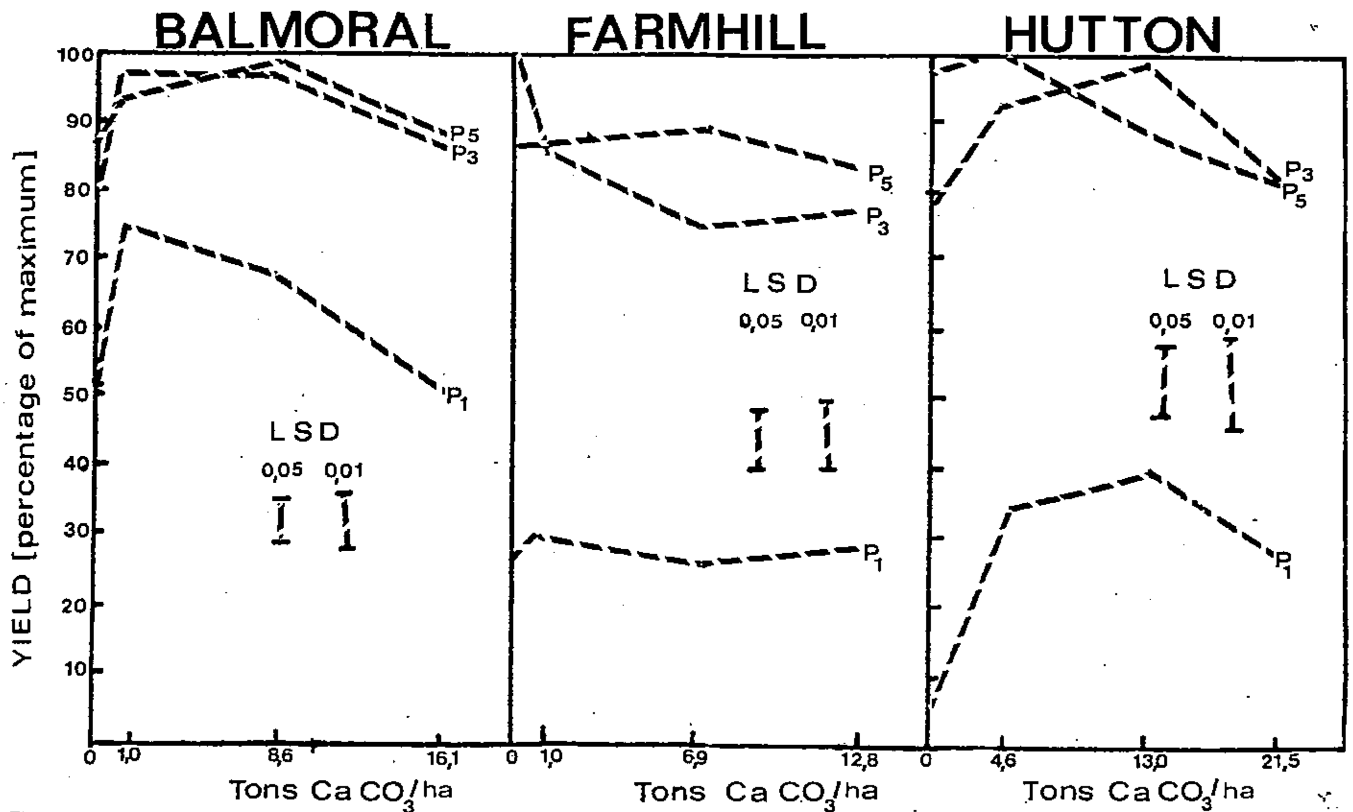

Fig 1 Response of Trudan (as a percentage of maximum yield) to liming over three phosphorus levels

The analysis of variance shows a highly significant quadratic effect of lime for the Hutton soil. Although the linear and cubic effects are also significant on the Farmhill soil, the main effect is quadratic as indicated by the numerical value. Table 5 shows that the maximum yield is obtained at the second level of lime addition (L2) for each soil. If the higher Ca requirement of lucerne is taken into account the result agrees closely with that of experiment 1. As was the case with the Trudan yields in experiment 1 there is a depressive effect at the highest lime level (Figure 3 Table 5) but this becomes less marked as the P-level is increased.

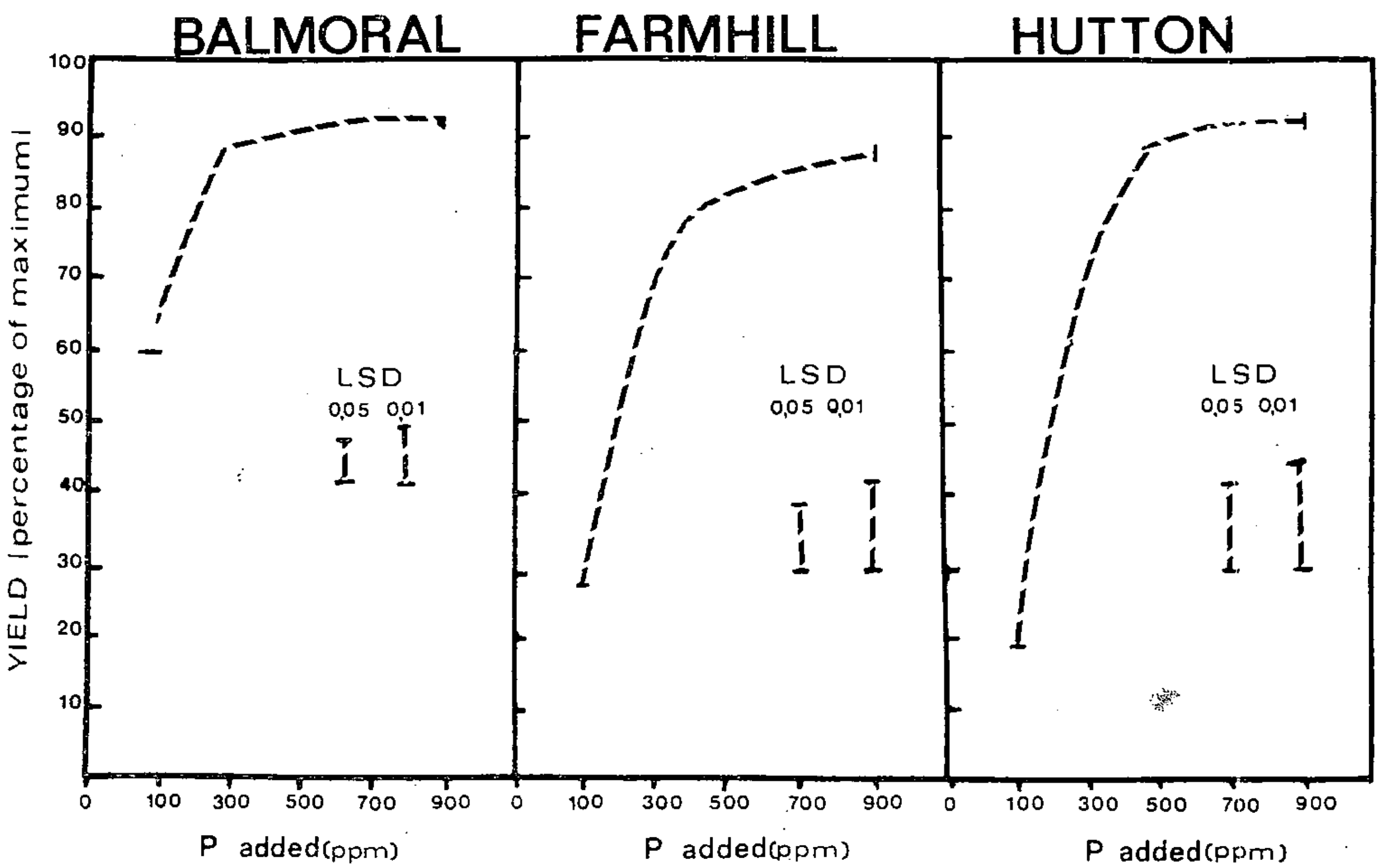

Fig 2 Response of Trudan to phosphorus for three soils (as a percentage of maximum yield)

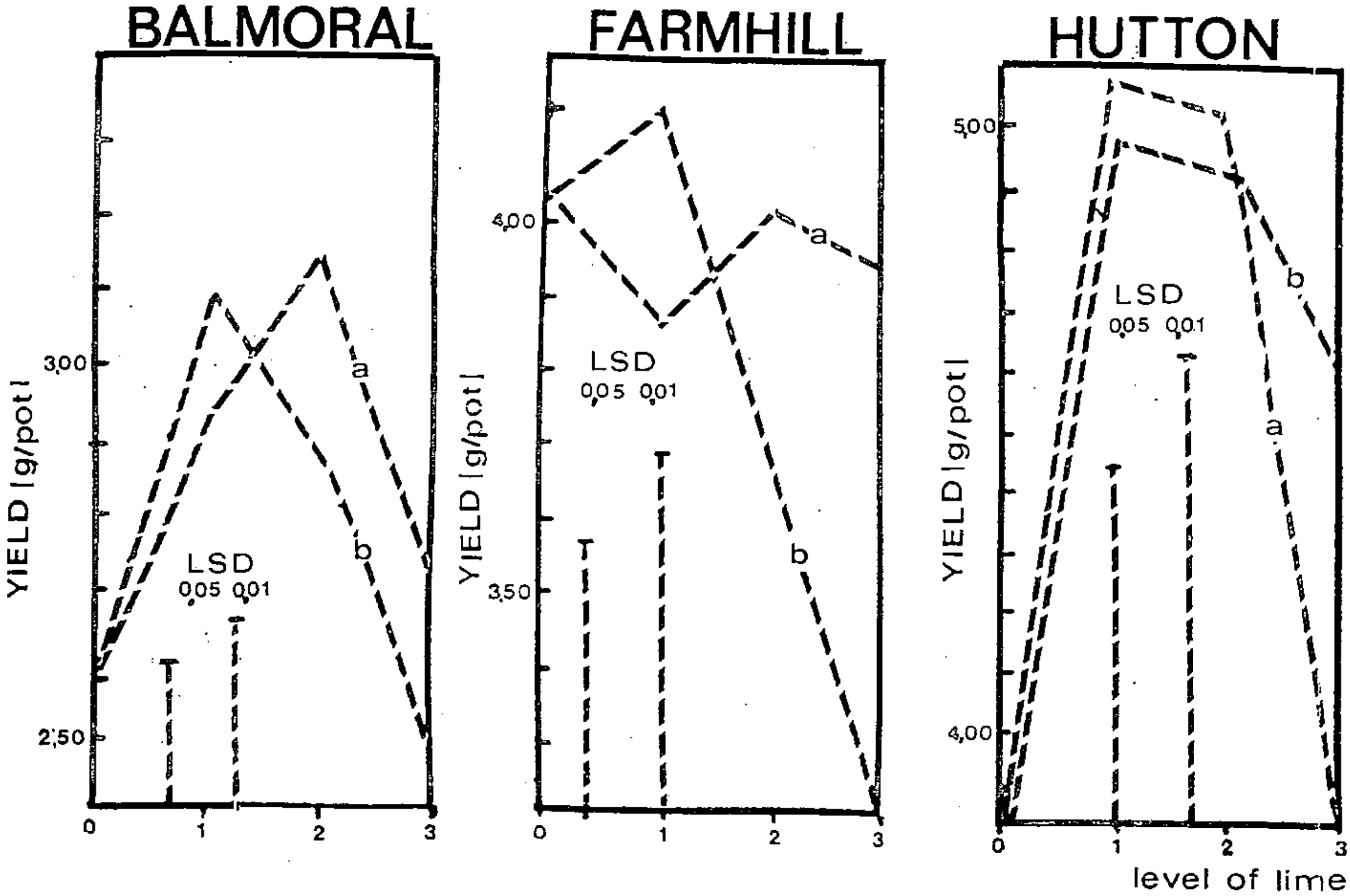

Fig 3 Mean response of Trudan to $CaOH_3$ [a] and Slagment [b] on three soils

The analysis of variance shows that the linear effects of phosphorus is dominant for both the Hutton and Farmhill soils. The roots follow a pattern similar to that of the tops (Figure 4).

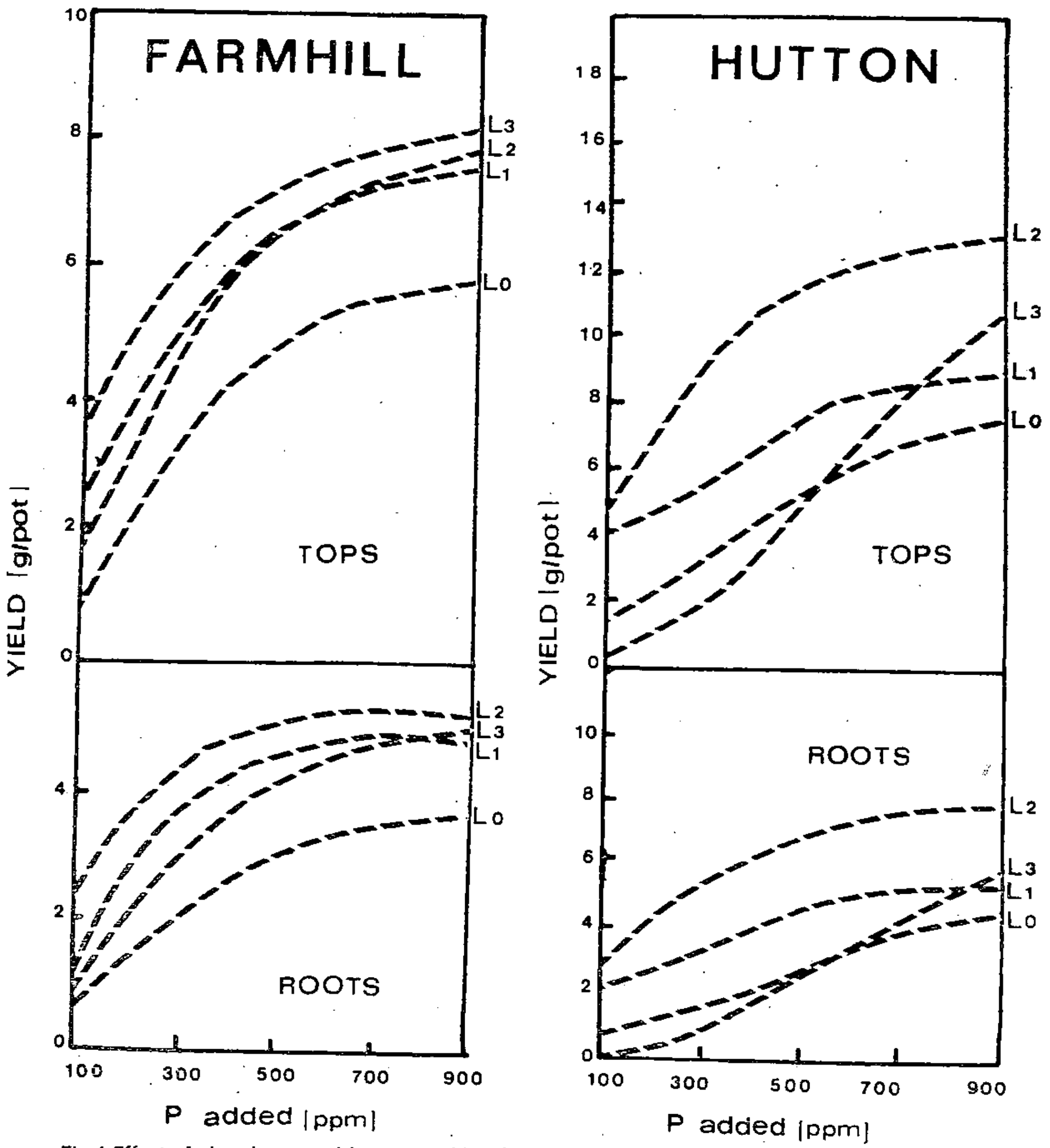

Fig 4 Effect of phosphorus and lime on yield of lucerne tops and roots

The development and distribution of the nodules on the roots presents an interesting picture. In the absence of, and at the first level of lime, nodules developed only at the place of inocculation: were exceptionally large but not numerous. At the higher lime levels small but numerous nodules were found over the entire root system. In all treatments the number of nodules increased with increasing level of phosphate application but there was no significant correlation between nodule effectiveness ratings and yield.

Discussion

Liming to satisfy Reeve's (1970) exchangeable aluminium index (EAI) is sufficient to diminish exchangeable Al to non-toxic levels. That the same response to lime is not found in the second experiment has to be attributed to the higher Ca-requirement of lucerne. The nodules play their role as well as they appear to prefer a higher pH and Ca status as indicated by their proliferation.

Liming to a pH value of 6,4 results in decreased yields for both crops. The most probable reason for this depressive effect is decreased P availability associated with increased Ca levels in the soil. Lewish & Racz (1969) and Gunary (1964) showed that the diffusion and dissolution of P in a soil with a high Ca content was reduced. The accumulation of Ca in the root environment by mass flow will aggravate the situation and Ca-phosphates even may precipitate at the root-surface (Miller, Mamaril & Blair 1970). This Ca accumulation is a function of plant species (Barber & Ozanne 1970). The data from these experiments fit this explanation.

On the soil with the highest initial exchangeable Ca content (Table 1) the overall effect of liming is depressive for the Trudan crop (Experiment 1, Figure 1). For the other two soils the effect of lime is initially positive and the depressive effect starts at a higher level of application as the initial exchangeable Ca content is lower (Table 1, Figure 1). Lucerne which has a higher Ca requirement does not show an overall depressive effect of lime for the Farmhill series but the relative response to lime of the Farmhill and Balmoral soils is the same as for the Trudan. Diminished micronutrient and potassium availability are also likely to be contributory factors but phosphorus availability at high lime levels appears to be the main limiting factor.

On the evidence of the data presented here, liming does not appear to diminish phosphorus adsorption effectively but on the contrary appears to reduce P availability by the formation of calcium phosphates at high lime levels. Evidence presented by Edwards (1968) supports this view.

The silica in Slagment was expected to compete with P for adsorption sites but this effect did not appear in increased P availability probably due to the low level of soluble silica subtended by the Slagment.

The phosphorus deficency of these soils is clearly illustrated by the quantities of phosphate needed to reach maximum yield. The application of such large quantities is not likely to be economic in the short term but if the residual effect is large which appears to be the case, the long term prospects might be attractive.

Opsomming

DIE INVLOED VAN BEKALKING EN HOË FOSFAATTOEDIENING OP PLANTEGROEI OP ENKELE NATALSE OXISOLS

'n Aantal potproewe met Trudan (Sorghum sudanense) *en lusern* (Medicago sativa L) *as toetsplante is op die Hutton, Farmhill en Balmoral grondseries gedoen om die reaksie op kalk (vier peile), Slagment (vier peile) en fosfor vyf peile) te ondersoek.*

Kalkbehoefte gebaseer op die uitruilbare aluminiumindeks was voldoende om maksimumopbrengs met Trudan te verkry, maar lusern het 'n effens hoër kalkpeil vereis. Bekalking tot pH 6,4 (volgens SMP) het 'n neerdrukkende effek op die opbrengs van beide gewasse gehad as gevolg van 'n vermeende verlaagde fosfortoeganklikheid.

Maksimum fosforreaksie op Trudan was verkry met 900, 500 en 300 dpm toegevoegde P vir Farmhill, Hutton en Balmoral grondseries onderskeidelik, terwyl lusern selfs groter hoeveelhede benodig het. Hierdie resultate vestig die aandag op die hoë fosforvasleggingsvermoeë van hierdie gronde en op die feit dat kalk die toestand nie kan reg stel nie.

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