INFLUENCE OF PREVIOUS LIMING, N AND P FERTILIZATION OF AN OXISOL ON GRAIN YIELD IN NAVY BEANS*

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Abstract

A field study was initiated towards the end of the 1973 rain season to assess some residual effects of lime, N and P applications to a moderately acid Oxisol (initial pH 5.6; LR 10 tons/ha) on grain yield in navy beans, **Phaseolus vulgaris** L., grown soon following maize silage. The Oxisol was a sandy clay loam (35:13:52). The design was a split-plot, confounded factorial with 4 levels of lime at 0, 7.5, 10.0 and 12.5 tons agricultural lime/ha; N at 0, 100, 200 and 300 kg N/ha as ammonium sulphate; and P at 0, 40, 80 and 120 kg P/ha as triple superphosphate. Lime was applied in November, 1970 and N and P rates repeated annually during 1971-73 with previous maize crops.

Grain yield increased linearly and significantly with lime up to a mean pH of 6.7 along with increases in residual Ca^{2+}, electrolyte, base content, Al-P, Fe-P, and Ca-P, and with reductions in extractable Mn and exchangeable Al. Yields at low N and P fertility were, however, drastically reduced as the optimum mean pH was exceeded. Yield increased linearly and highly significantly with N and P fertilization. Yields were low where lime, N and P were not applied together. The data indicate that for the Oxisol, which had less than 0.2 me/100g of exchangeable Al in the absence of applied lime and N, liming to reduce exchangeable Al cannot be taken as a criterion for liming but that optimum pH, adequate balance of ion ratios and adequate conservation of soil nutrients would be appropriate.

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Introduction

Liming of soils to a desired optimum pH has been a conventional soil management practice in western temperate agriculture where the accepted liming concept resulted in acid mineral soils being limed to pH 6.5-6.8 (Truog, 1947; Volk **et al.**, 1974; Coleman and Thomas, 1967; McLean, 1971). The extension of the concept of liming to pH 6.5-6.8 to highly weathered tropical soils has been challenged by a new and well-supported school of thought on the premise that the benefical effects of lime in enhancing nutrient availability are doubtful in situations where nutrients supply is not restricted to native soil supply (e.g. Kamprath, 1970; Reeve and Summer 1970). The new school considers that lime applications should ideally be based on the neutralization of exchangeable Al to a low level of about 0.2 me/100 g soil (Reeve and Summer, 1970).

Some studies have indicated that the contention of the new school of thought may be applicable in many field situations (e.g. Foster, 1970; McClung **et al.**, 1961; Mikkelsen, de Freitas and McClung, 1963). However, other research works and reviews (De Freitas and Pratt, 1969; Locsin, 1953; Hubell, 1971; McLean, 1971; Reid, 1970; Foy **et al.**, 1973; Beckett, 1972; Moore, 1972 and Munson, 1968, show intricate interactions in the soil and plant. The influence of the soil and plant factors determines the nature of response of each plant type under the set conditions. Thus, even where lime has been applied to a level where exchangeable Al would be "neutralized" as viewed by the said school, response to lime at a higher level may still be found due to the effect of lime on other ion relationships and where crop plants have a higher Ca requirement. If particular essential nutrient elements are in short supply the lime effect would be small, or even negative.

As many acid soils growing beans in Tanzania require liming, it was the objective of this study to evaluate grain yield response in navy beans, **Phaseolus vulgaris,** to previous applications of lime at varied N and P levels, in part to assess the applicability of the new liming concept to an Oxisol in Tanzania and to add to the search for information basic to planning investments in soil management and fertilizer use under Morogoro and similar situations in Tanzania. This study is based on plots previously used to assess some lime x N x P effects on some nutrient interrelationships in the soil and plant and their relation to yield response in maize*. Some of the soil characteristics observed in surface soil samples taken during the previous year are used as aids in the interpretation of the navy beans grain yield data.

*H.O. Mongi, 1974. Lime, nitrogen and phosphorus effects on some chemical characteristics of an Oxisol, leaf element content and yield in uplands rice and maize at Morogoro, Ph.D. Thesis, University of Dar es Salaam.

Materials and Methods

The investigation was carried out during the 1972/73 season based on field plots on which maize response to lime; N and P was assessed during the 1970/71—1972/73 growing seasons. The design was a split-plot, confounded factorial with 4 levels of lime at 0, 7.5, 10.0 and 12.5 tons agricultural lime/ha (ECCE* 90%); N at 0, 100, 200 and 300 kg N/ha as ammonium sulphate; and P at 0, 40, 80 and 120 kg P/ha as triple-superphosphate. Lime was the main treatment. The two-factor and three-factor interactions were partially and completely confounded, respectively. The sub-treatments were in blocks of 4 units, all units being in 9 replications (Cochran and Cox, 1964). Lime was applied in November, 1970 and the N and P applications repeated annually with the three previous maize crops.

The soil is classified as an Oxisol (Kesseba, Pitblado and Uriyo, 1972) and was a well-drained sandy clay loam (35:13:52). Some of the initial soil characteristics were : CEC 12.85 me/100 g; electrical conductivity 0.13 mmhos/cm; C/N ratio 11.7; and lime requirement averaged 10.0 tons/ha at pH 5.6. Some of the accumulated residual surface soil (0-8 cm) characteristics as determined, according to Black (1965), in samples taken at the silking stage of the previous year's maize crop are summarized in Table I.

The maize plants were removed as silage at the milk-stage of the grain and the plots cleared of all weeds before ploughing. Two to three navy bean seeds per hole were sown and thinned to one plant one week after germination. Insects were controlled with one spray each of Dimecron and Endosulfan. Plot size was 10 sq m and spacing was 20 x 20 x 30 cm, the harvest area from the middle of the plots being 5 sq. m.

Plants were hand-pulled on maturity and hand-threashed. The grain was sun-dried for 3 days and weighed. Statistical analysis was done on a 1901 ICL computer at the Scientific Computing Centre, University of Dar es Salaam, using an ANOVA program incorporating partitioning of effects by polynomial regression up to the third-degree polynomial (Koda, Mongi and Reichert, 1972).

Results

NAVY BEAN GRAIN YIELD

Figures 1, 2 and 3 summarize the navy beans grain yield data. Previous lime applications were associated with highly significant yield

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* ECCE = Effective calcium carbonate equivalence.

TABLE I — SOME CHEMICAL PROPERTIES OF THE OXISOL AS DETERMINED IN SAMPLES TAKEN AT THE SILKING STAGE OF THE PREVIOUS YEAR'S MAIZE CROP AND AVERAGED FOR THE LIME x N AND LIME x P RELATIONSHIP

Treatment Lime t/ha	Treatment Fertiliser kg/ha	Soil pH 1:5 (H_2O)	Exch. Al me/100 g	Elect. Cond. mmhos/cm	Inorg. N (NH_4+NO_3) kg/ha	Inorganic P fractions, ppm Al—P	Fe—P	Ca—P	Total	Extract. Mn (pH 3.0) ppm
0	0 N	5.49	0.28	0.004	51.17	23.0	72.0	40.3	135.3	60.1
0	100 N	5.08	0.45	0.120	50.95	29.4	74.5	47.6	141.3	84.7
0	200 N	4.98	1.36	0.298	44.65	23.0	68.6	49.7	155.5	135.1
0	300 N	4.72	1.74	0.316	67.13	27.2	78.5	33.1	138.8	165.5
7.5	0 N	6.99	0.13	1.056	45.06	23.8	65.5	44.9	133.2	49.8
7.5	100 N	6.56	0.15	0.422	46.55	26.7	65.0	57.7	149.4	52.4
7.5	200 N	6.07	0.30	0.889	51.70	27.5	68.4	49.8	145.7	49.9
7.5	300 N	6.10	0.15	0.656	60.71	25.9	70.4	42.2	138.5	53.7
10.0	0 N	6.81	0.12	0.378	50.75	31.4	75.4	52.6	159.4	47.8
10.0	100 N	6.58	0.12	0667	48.86	22.9	65.1	46.4	134.4	53.2
10.0	200 N	6.81	0.14	1.033	47.91	31.9	91.8	62.1	185.8	54.2
10.0	300 N	6.06	0.31	0.811	46.96	26.3	69.6	44.3	140.2	66.4
12.5	0 N	6.89	0.12	0.844	45.06	32.4	68.1	60.2	160.7	53.4
12.5	100 N	7.13	0.11	0.611	45.08	25.1	63.1	52.3	140.5	53.8
12.5	200 N	6.91	0.14	0.983	47.85	25.0	57.4	52.1	134.5	53.8
12.5	300 N	6.66	0.16	0.855	53.74	31.7	69.8	50.6	152.1	48.0
0	0 P	5.11	0.94	0.098	57.87	19.7	58.3	47.3	125.2	117.9
0	40 P	4.98	1.08	0.247	56.45	23.0	67.2	38.9	129.1	122.8
0	80 P	5.26	0.99	0.149	52.68	26.1	76.0	43.7	145.8	113.0
0	120 P	4.90	0.81	0.244	49.91	33.8	92.1	40.8	166.7	91.7
7.5	0 P	6.66	0.23	0.900	64.51	21.7	63.6	44.9	130.2	57.3
7.5	40 P	6.51	0.16	0.711	50.73	20.1	66.5	37.9	124.5	53.2
7.5	80 P	6.40	0.21	0.867	41.74	29.7	66.5	56.6	152.8	47.9
7.5	120 P	6.14	0.13	0.544	47.05	32.4	72.7	51.5	156.6	47.4
10.0	0 P	6.50	0.14	0.444	46.01	20.9	73.0	35.3	129.2	60.5
10.0	40 P	6.59	0.28	0.922	46.01	28.2	69.5	39.8	137.5	62.6
10.0	80 P	6.48	0.14	0.667	50.28	32.0	77.8	70.0	179.8	48.9
10.0	120 P	6.71	0.13	0.856	52.18	31.5	81.6	60.2	173.3	49.9
12.5	0 P	6.80	0.13	0.800	45.48	14.3	63.0	60.8	138.7	55.8
12.5	40 P	7.17	0.12	0.870	49.30	29.3	63.1	59.8	152.2	53.1
12.5	80 P	7.00	0.12	0.856	45.25	31.1	69.1	46.9	147.1	53.9
12.5	120 P	6.62	0.16	0.767	51.70	39.4	62.6	47.6	149.6	46.2
Overall mean		6.23	0.36	0.621	50.26	27.1	70.2	24.4	121.7	67.6
S.E. diff. of means		0.24	0.13	0.242	6.15	4.6	6.7	8.81	—	8.7

increases, the overall trend being quadratic and very highly significant. Yields increased linearly and highly significantly up to the 10.0 tons lime level but decreased sharply with lime increase to 12.5 tons/ha. Mean grain yields, with the 10.0 tons lime rate ware increased by 92%, or by 315 kg, above those without lime.

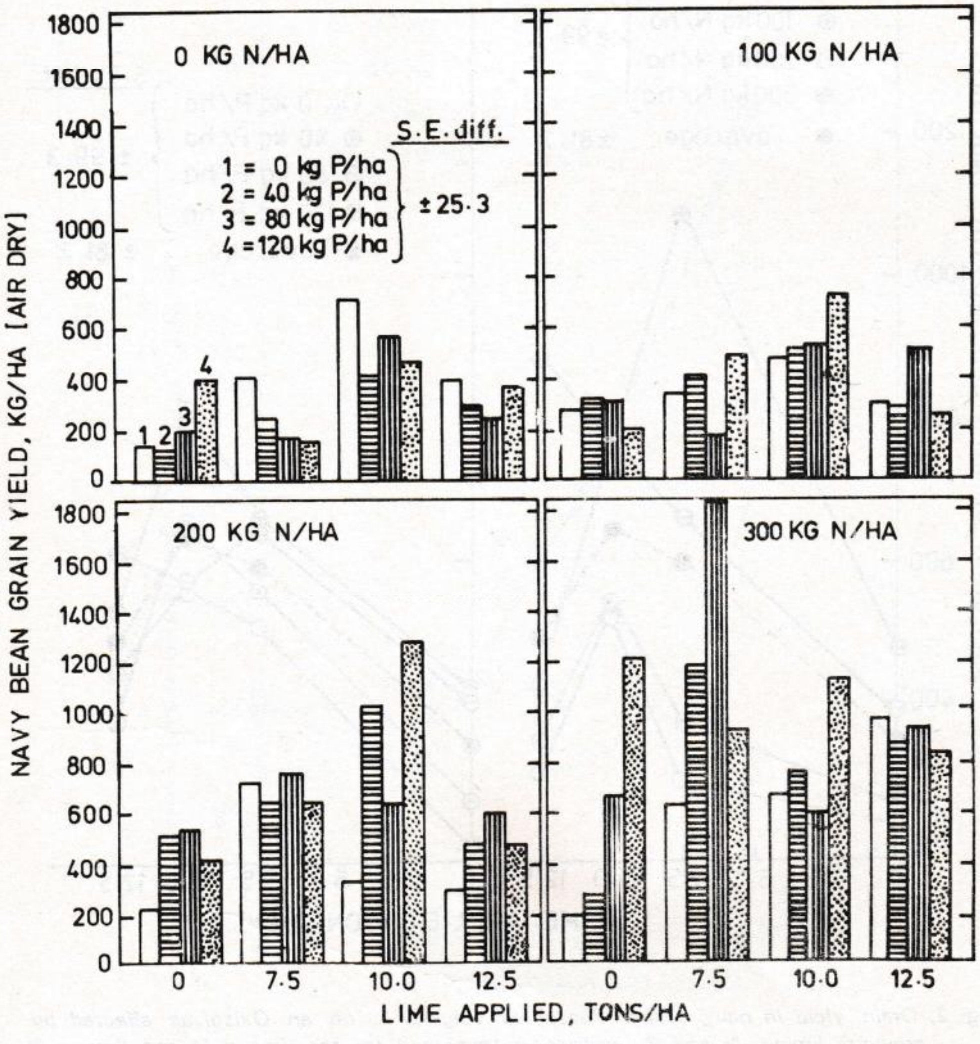

Fig. 1 *Effect of previous liming, N and P fertilization of an Oxisl on grain yield in navy beans, Phaseolus vulgaris L.*

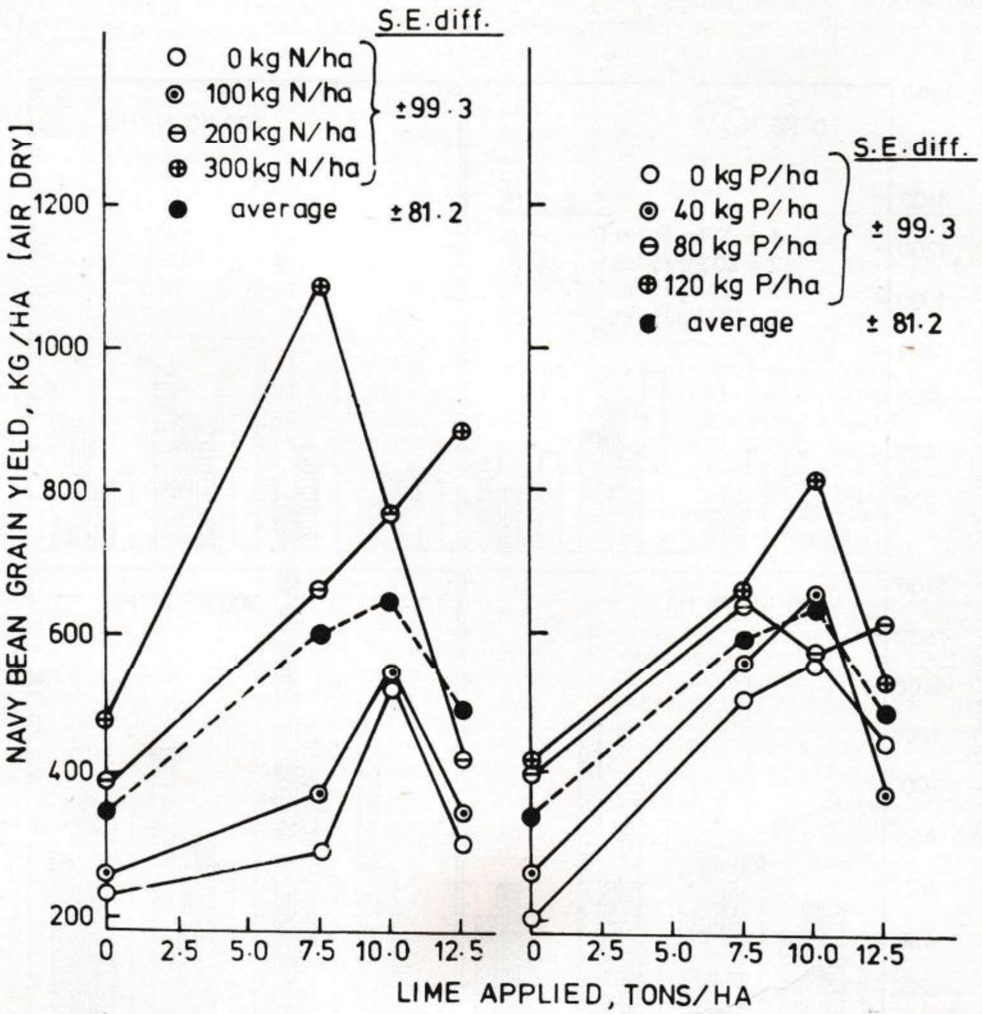

Fig. 2. *Grain yield in navy beans, Phaseolus vulgaris L. on an Oxisol as affected by previous liming, N and P fertilization (averaged for the lime x N and lime x P relationships).*

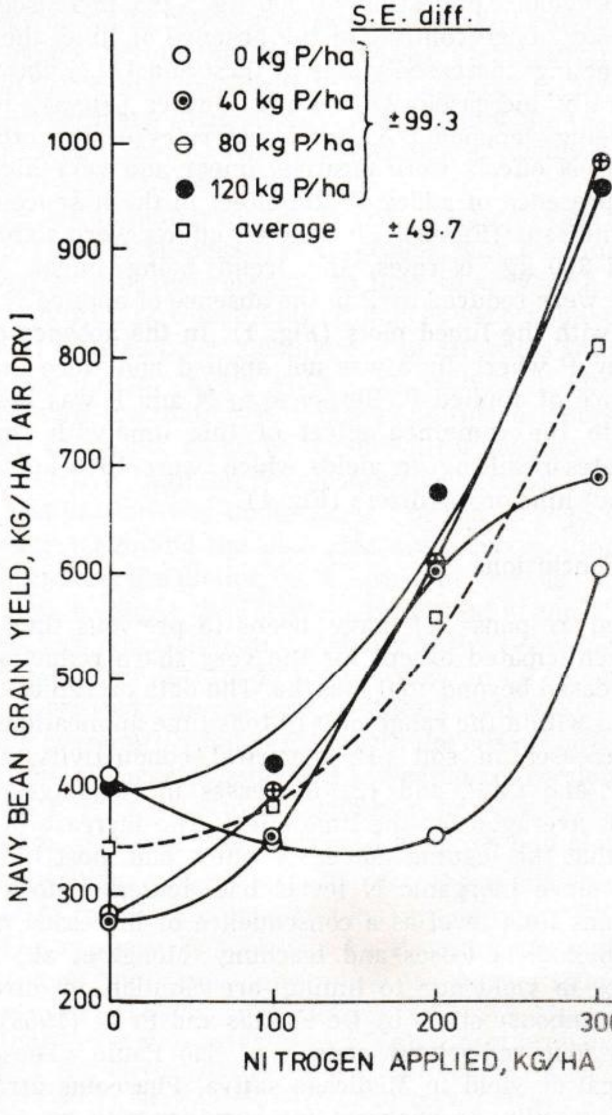

Fig. 3 *Effects of previous N and P applications to an Oxisol on navy beans grain yield (averaged over lime).*

Linear and very high or highly significant yield increases were respectively recorded for previous N and P applications at all lime rates, except for minor variations in response to P with the 12.5 tons lime rate (Fig. 1). The highest mean response to N was in association with the 7.5 tons lime rate where the previous application of 300 kg N/ha increased yields by 281%, or by 808 kg, above control. In the absence of lime, the highest N and P rates **respecting** increased yields by 95% and 111% above controls.

Yields generally increased with N and P rates (Fig.3), response to either element being dependent on increased rates of the other. In the N x P relationship, N effects were positive, linear and very highly significant only in the presence of added P, the effect in the absence of P being quadratic and significant (Fig. 3). Phosphorus effects were significant only with the 200 and 300 kg. N rates, the trend being linear and highly significant. Yields were reduced by P in the absence of applied N, this effect **being associated with the limed plots (Fig. 1). In the absence of N. yields** were increased by P where lime was not applied and were increased by lime in the absence of applied P. Response to N and P was best with the 7.5 tons lime rate, the combined effect of this lime with the 80 kg. P and 300 kg. N rates resulting in yields which were 1670 kg. or, 1246% above those without lime or fertilizers (Fig. 1)

Discussion and Conclusions

The observed response of navy beans to previous lime, N and P applications was anticipated except for the very sharp reduction in grain yield as lime increased beyond 10.0 tons/ha. The data of Table I shows that the yield increases within the range of 0-10 tons lime applications generally followed (1) increases in soil pH, electrical conductivity, Ca^{2+}, total bases, Al-P, Fe-P and Ca-P, and (2) decreases in exchangeable Al and extractable Mn, as averaged for the lime effect. The increase in yield with N rate suggests that the legume tapped N which had most likely leached to lower depths, since inorganic N levels had decreased to a minimum low at the 10.0 tons lime level as a consequence of increased nitrification and subsequent biological losses and leaching (Mongi **et al.,** 1974).

The increases in yield due to liming are similar to direct effects reported for a greenhouse study by De Freitas and Pratt (1969) with four acid latosols and four red-yellow podsols of Sao Paulo. These workers found that dry matter yield in **Medicago sativa, Phaseolus atropurpureus** and **Stylosanthes gracilis,** as analysed for curvilinearity up to the third-degree polynomial, reached a maximum at different optimum pH on each soil. In their work, response for **Medicago sativa** was positive on all soils up to pH 7.0 except on one soil where the optimum pH was about 6.5, while

Stylosanthes and **Phaseolus** reached optium pH close to 6.5 except that on one soil yields were reduced linearly with pH increase for **Stylosanthes** and no effects occurred for **Phaseolus.** They, however, established optima of pH 6.1 for **Phaseolus** and 6.4 for **Stylosanthes** and **Medicago sativa.** With applications of Mn to two of the limed soils they observed that Mn toxicity occurred at low pH but that Mn increased yields linearly beyond pH 6.5. As a result De Freitas and Pratt (1969) suggested that Mn deficiency probably occurred in the neutral pH range and that the tropical legumes were intolerant of Mn toxicity, **Phaseolus vulgaris** probably being more tolerant to both Mn toxicity and deficiency.

Studies with similar soils of Brazil ("Campo Cerrados") by McClung **et al.** (1957) and by Mikkelsen **et al.** (1963), with one lime application to pH **6.0, showed soya beans' response to lime to vary with fertility, yields in**creasing significantly where lime, P and K were applied together. Norris **et al.** (1967) showed poor nodulation in **Stragalus sinicus** L. on the soils without inoculation, even with lime-pelletting the seed, and better nodulation with inoculation and lime-pelletting of the seed. This suggests that liming would not alone be beneficial for legume production on soils low in both native mineral N and infective rhizobia unless inoculation or nitrogen fertilization was undertaken. In the Morogoro study inoculation was not undertaken and the increased response to lime with previous N rates well supports the findings with Brazillian Oxisols.

The poor response to N without lime and at low lime rates may be a function of low transamination activity with consequent low amino acid synthesis. Barker **et al.** (1966) showed this to be the case with **Phaseolus vulgaris., increased amino acid synthesis and yield increase occuring with liming or the provision of CO_3^- with the NH_4-N or by the application of NH_4CO_3. These workers associated increased conversion of NH_4-N to non**toxic metabolites in roots to the dominant process by which acidity control **through ammonium nutrition improved the growth of plants.**

As the exchangeable Al data shows, there was little difference in exchangeable Al for the 7.5 and 10.0 tons lime rate and with N in the absence of lime. The increase in Al–P and Fe–P with lime, and in extractable Mn at the 12.5 tons lime rate, indicate that the factors influencing yield in the Oxisol are most probably not exchangeable Al. Manganese varied in the soil in rather the same way as Al and is also most probably not an important factor under the circumstances. The yield reductions at the 12.5 tons lime rate are probably associated with reduced nutrient uptake, as observed elsewhere (Mongi **et al.,** 1974) as a result of nutrient imbalances in the soil and plant.

The importance of adequate nutrient balance in the soil and plant has been severally re-empnasized (e.g. Beckett, 1972; Munson, 1968;

Olsen, 1972; Le Mare, 1972; McLean, 1972; and Trolldenier, 1973). Thus, Anderson (1970; 1972) obtained marked direct responses to P and K by groundnuts in Dodoma and field beans in Kilimanjaro only where these nutrient elements were applied together with lime. The work of Herbert (1970) with groundnuts in Zambia also showed the importance of adequate nutrient balance, a soil K/Ca ratio above 0.2 me/100 g being detrimental to groundnuts through an increase in the severity of "pops" disease. Low transamination activity leading to amino acid synthesis was, thus, probably implicated in the present study since the soil K/Ca ratios in the untreated soils was less than 0.2.

Under the same Morogoro soil conditions, Mahatanya (1972) showed similar N and P effects with soya beans and associated the effects with increased uptake of N, P, K, Ca, S and Na, as well as with increased LAI and NAR.

In a study carried out in the season preciding Mahatanya's work, Uriyo (1974) found positive and significant responses in soya beans yield due to P, but not due to N or K. The season had been drier than that of the following year of Mahatanya's study. Tag **et al.** (1972) reported positive and significant responses to P and K with soya beans, field beans and groundnuts in 19 districts of Kenya on rather similar soils, the response to P being greater in the presence of K except at one site at Homa Bay. These findings in direct responses emphasize the need for adequate nutrient balance and well support the residual response observed in the current investigation.

The lime x P x N interaction in this study indicates that liming to an eventual pH 6.5—6.8 would enhance residual response to N and P for crops following cereals. The data also indicate that lime effects can be quite long lasting (as is apparent in studies on the same plots this season). The results indicate that for the Oxisol, which had less than 0.2 me/100 g of exchangeable Al in the absence of lime and N, liming to reduce exchangeable Al cannot be taken as a criterion for liming, but that optimum pH, adequate balance of ion ratios and adequate conservation of soil nutrients would be more advisable.

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