RESIDUAL EFFECT OF PHOSPHATE TOP-DRESSING ON A YELLOW-BROWN LOAM

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Annual phosphate topdressing has been needed on the yellow-brown loams of Taranaki to maintain vigorous productive pastures. There is, however, a wide range of opinion as to what is the optimum rate of topdressing and what is the optimum phosphorus status for pasture production.

The work on this problem by Soil Bureau, D.S.I.R., has been in two parts: First, a comparison of soils collected from fields which had been topdressed at different rates; second, a field trial to evaluate the residual effects of phosphate topdressing. The work was done on New Plymouth black loam, which is typical of the yellow-brown loams of North Taranaki.

The sites for the first part of the work had all been under pasture for at least 25 years. They were freely drained and had been used solely for grazing. The phosphate topdressing histories of the areas sampled were:

(a) One pair, no phosphate (No-P).

(b) One pair, 20-30 lb P/ac/year for 25 years (Mod-P) (2-3 cwt superphosphate).

(c) One pair, 60–80 lb P/ac/year for 8 years (High-P) (6-8 cwt superphosphate).

The results of this comparison have been published (Saunders, 1959) and some of these are shown in figs. 1 and 2.

There was an increase of total phosphorus content of the soils following topdressing, but only to a depth of 5 in. The increase at O-2 in. was much.greater than at 2-5 in. The increased phosphorus content roughly accounts for all the phosphate applied, taking into account the probable amounts removed as farm products. The phosphate added to the Mod-P soils roughly equals that added to the High-P soils (625 lb and 560 lb P/ac respectively), and greater loss as farm products accounts for the lower phosphorus content of the Mod-P soils.

The accumulation of phosphorus in the topdressed soils is mainly in inorganic forms of phosphorus; the amount present. as organic phosphorus has hardly increased. Burgess and Davies (1951) found a similar result in a yellow-brown loam near Stratford which had been under pasture for 25 years.

The concentration of the phosphate in a restricted amount of soil has the benefits of fertiliser placement, but it has the disadvantage that in dry spells it is no longer available, since the top inch of this soil can dry out to wilting point in one week without rain (Saunders *et al,* 1963).

A pot experiment showed that the level of available phosphate in these soils was well evaluated by the Truog test of the Depart-

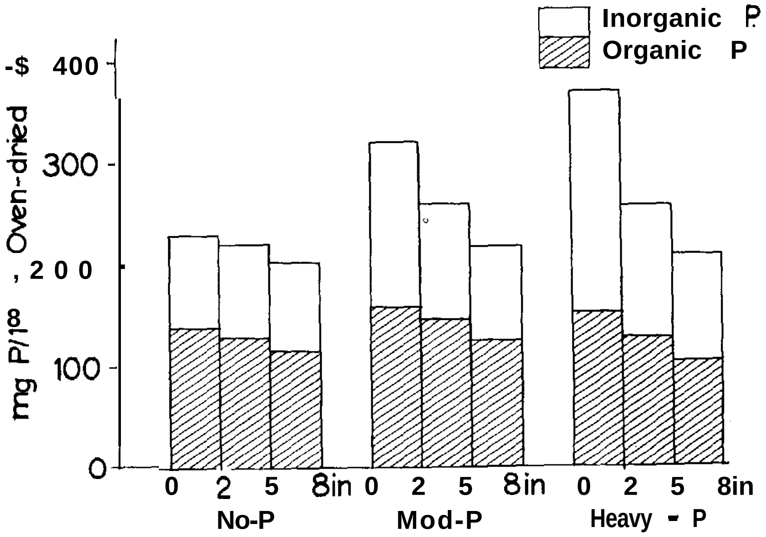

Figure 1.-Total, inorganic and organic phosphorus in New Plymouth black loam, which has had no phosphate, phosphate at moderate rates, and phosphate at high rates.

ment of Agriculture (fig. 2). Dry matter yield increased with the Truog value and the degree of response decreased. Although this was a pot trial and radish was used as the crop, the levels of response taken from it relate very closely to field experience.

Degree of response	Truog values Pot trial	 Field experience*
large	o - 3	o - 3
medium	4 - 7	3 - 7
small	8 -15	7 -13
none	16 -	13 -

*Pers. comm. A. C. Burgess and G. R. Moss.

The Truog values for No-P, Mod-P, and High-P soils are marked in fig. 2. The No-P soils fall into the top of the large-response category, the Mod-P into the medium-response, and the High-P soils are in the small-to-no-response group. Although the amount of phosphate applied to the Mod-P soils is of the same order as that to the High-P soils, the level of available phosphate has not built up proportionately. The high rate of application on the High-P soils has kept the level of available phosphate well ahead of the losses in farm products and by phosphate-fixation processes.

Since little or no response to phosphate can be expected from the High-P soils with a soil test of 15, the signs are that phosphate topdressing could be stopped or at least reduced. The question is for how long or to what level?

Some information on this question has come from the field trial which measured the residual effect of phosphate topdressing. The field trial was run in collaboration with the New Plymouth office of Department of Agriculture on the farm of the late Mr W. Hardwick-Smith. We gratefully acknowledge the willing help of all concerned, particularly Messrs A. C. Burgess and G. R. Moss.

The object of the trial was to compare the effectiveness of phosphate two and three years after application (the residual effect), with the effectiveness of phosphate in its first year of application. The trial was laid out in four blocks. These were topdressed with double superphosphate in four successive years

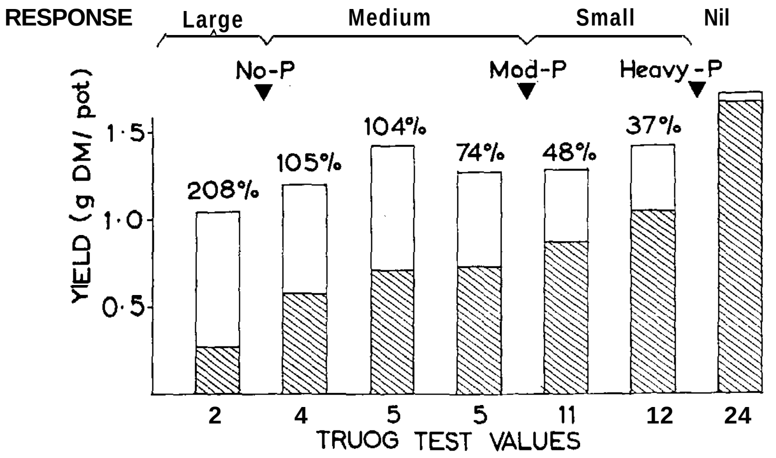

Figure 2.-Relation between Truog P test values and phosphate response on New Plymouth black loam.

as follows: Block 1, September 1954; Block 2, August 1955; Block 3, August 1956; and Block 4, August 1957.

The whole area received a basal dressing of KC1 and $MgSO_4$ each spring.

The rates of topdressing on each block were:

Block 1	0	20	40	80	160	lb P/ac.
Block 2	0	20	40	80	160	lb P/ac.
Block 3	0	20	40	80		lb P/ac.
Block 4	0	20	40	80		lb P/ac.

In 1955-56 a comparison was made between the response to first-year phosphate on Block 2 and the response to second-year phosphate on Block 1. In 1956-57 the comparison was made between first-, second-, and third-year phosphate and in 1957-58 the phosphate of four years was compared.

The results. of this field trial will be reported in detail shortly. (Saunders *et* al, 1963). In this paper, rather than give the results for the individual years of the experiment, we give mean values of three years of the trial to show the general trends. For example, the first-year phosphate response curve is calculated from three curves for phosphate applied in 1955, 1956 and 1957. The second-year response curve is the mean from three years, and the third-year response curve is the mean from two years.

The soil-pasture-phosphate relationships of the fast-growing spring and early summer pasture were very different from those of the slow-growing autumn and winter pasture. In accord with many other phosphate field trials the degree of response to added phosphate was least in spring and increased through summer to be greatest in autumn and winter. The phosphorus content of the pasture was highest in spring and fell to its lowest levels in summer and autumn. In winter it lay between the autumn and spring levels.

This trial showed that the residual effect of phosphate topdress: ing was subject to seasonal variation. In spring, when the degree of response to phosphate was low, the response curves for the second- and third-year phosphate were similar to that for the first-year phosphate (fig. 3). In summer this similarity was more striking, since the degree of response was greater. In this period of rapid growth the phosphate topdressing was showing a high residual effect in that there was no difference between the effectiveness of the first-, second- or third-year phosphate.

In contrast, in autumn the,response to first-year phosphate was much greater than to the residual second- and third-year phos-

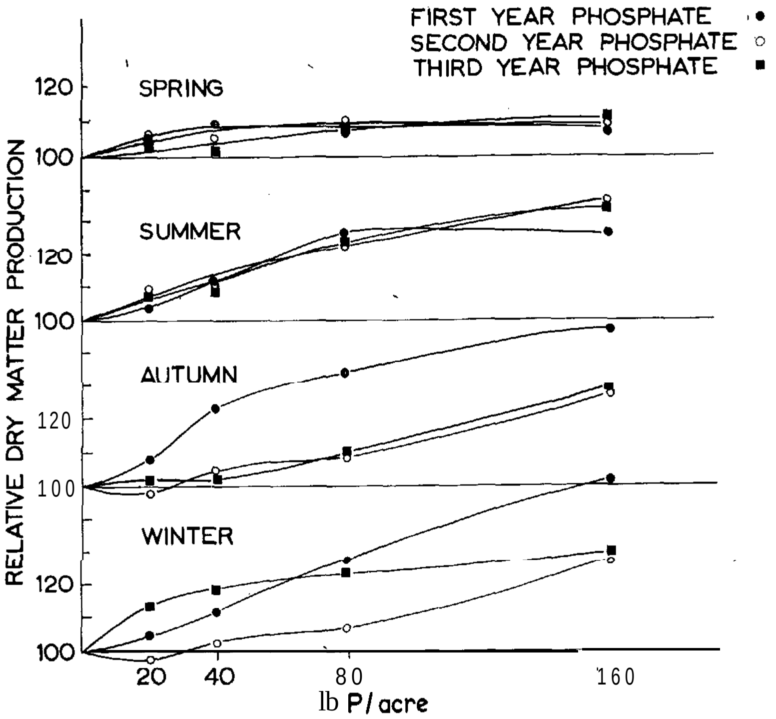

Figure 3.-Relative dry matter production to different rates of phosphate topdressing in its first, second and third year after application.

phate. For example, 80 lb P/acre as second- or third-year phosphate gave the same degree of response as 20 lb P/acre of Erst-year phosphate. The lower rates of 20 and 40 lb P/acre as second- and third-year phosphate gave no response.

In winter the second-year phosphate showed a small residual effect, but the third-year phosphate showed a good residual effect at the lower rates of topdressing, but not at the highest rate. Some of the difference between second- and third-year phosphate is not statistically significant, but there still remains an inexplicable difference.

Summarising: In the period of rapid pasture growth (spring and summer) the degree of response to phosphate was lower, the phosphorus content of the pasture was higher, and the effectiveness of residual phosphate was greater than in the period of slow pasture growth. These differences between the two periods of the year point to the soil and residual fertiliser phosphorus being more available to pasture in spring and early summer than in autumn and winter.

Discussion

The availability of soil phosphorus is determined by both soil and plant factors. The soil factors govern the concentration of phosphate in the soil solution and the rate at which it can be renewed. This rate of renewal is an important feature of phosphate nutrition of plants. The amount of phosphate in the available soil moisture of the High-P soils was 0.012 lb P/ac (2 oz superphosphate/ac). However, the demand of the rapidly-growing spring pasture was 0.14 lb P/ac/day (23 oz superphosphate/ac/day) . Hence the phosphate in the soil solution was renewed over-ten times a day.

Phosphate enters the soil solution by three major processes: dissolution of inorganic forms of soil and fertiliser phosphorus, mineralisation of soil organic phosphorus, and breakdown of plant and animal residues.

Though phosphate is being continually supplied to the soil solution, there is also a continual sorption of it from solution by the soil colloids which maintains the low concentration. Over short periods this sorption is reversible and as the plant withdraws phosphate the sorbed phosphate will re-enter the solution to maintain the phosphate concentration. Over a long period the sorbed phosphate will become fixed and is no longer able to reenter the soil solution. The extent and, rate of all these processes are governed first by the nature of the soil,, that is, its degree of weathering and leaching and its parent material. In addition these processes are influenced by the moisture content and temperature of the soil, and seasonal variations in these factors may well alter the concentration of phosphate in solution and its rate of renewal.

The phosphate in the soil solution is available to the plants only' when their roots can reach it and can absorb it. Therefore the density of roots in the soil and the soil moisture content could be important factors in phosphate availability, The work of W. A. Jacques and his colleagues at Massey College indicates that there is a greater density of roots under the grass-dominant spring pasture than under the clover-dominant autumn pasture and that lack of moisture in summer retards root renewal. These factors may contribute to the higher availability of soil phosphorus in spring than in autumn. These are just two of several plant factors.

The availability of the soil and fertiliser phosphorus at any time of the year involves the integration of soil and plant factors. The relative contributions of each factor are still largely unknown. Their evaluation is probably a good line of research toward improved utilisation of our phosphate 'resources.

In 'addition to giving information on the seasonal variation of soil-plant-phosphate relationships discussed above, this work provides some information which may improve the utilisation of phosphate on the yellow-brown loams of Taranaki.

After several years of high rates of topdressing. the High-P soils discussed were giving a Truog phosphorus test of 15, indicating little further response to phosphate fertiliser. When these yellow-brown loams reach this level it is probable that a lower rate of phosphate topdressing can be used. But in view of the lower effectiveness of residual phosphate fertiliser in autumn and winter it would not be advisable to stop topdressing altogether but to use a low rate in late summer or autumn.

It is common practice in Taranaki to split the annual phosphate topdressings (both maintenance and the heavier dressings used when establishing new pastures) and to make applications in autumn and spring. Since there appears to be a very high residual effect in spring and summer, it is probably better to use all the annual topdressing as a single application in early autumn to cope with the lower availability of the soil phosphate in autumn and winter: The residual effect would meet the need of the spring pasture.

A change to phosphate topdressing solely in autumn and to low rates on the high-phosphate-testing soils would have to be done without interfering with the potassium needs of the soils. Work at Soil Bureau (Saunders and Metson 1959) indicated that especially on low-potassium-testing soils, potassium is best applied as small frequent dressings rather than large infrequent dressings. Hence, even if phosphate topdressing in spring is stopped, it seems advisable that potassium topdressing should continue.

The residual effect of fertiliser phosphate in spring could well be of general occurrence, but there are two points to consider. In the yellow-brown loams of Taranaki the added phosphate accumulates mainly as forms of aluminium phosphate (Saunders 1959). This has been attributed to its high content of allophane and associated amorphous aluminium oxides. In soils in which iron plays a greater part in retaining the fertiliser phosphate the situation may not be quite the same: In soils in which organic matter levels are building up much of the fertiliser phosphate is converted to organic phosphorus (Jackman, 1960). It is probable that in this form it would not show a high residual effect.

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DISCUSSION

Q. (K. O'Connor): Was there good insect control in the trial, with reference to the possible part played by roots in seasonal availability of residual phosphate?

A. Yes. There was no sign of grass grubs themselves in soil samples. DDT was applied,

Q. (A. Pantall): How much phosphate was actually fixed in the soil?

A. To determine how much phosphate is fixed it is necessary to measure how much was used. Because the clippings were returned to the plots it is not possible to calculate the uptake of phosphorus and hence the amount fixed.

Q. (J. Stitchbury): What level of autumn topdressing could be recommended on paddocks with a high phosphate soil test?

A. The design of this trial was directed toward measuring residual effect and this other important question of maintenance rates could not be answered. Further trials along the lines of those used by Rukuhia Soil Research Station in the Waikato are needed. As a guestimate based on the results of the trials of Rukuhia and on the properties of the respective soils, I would think about 40 lb P/ac (4 cwt superphospate/ac.) would be required to maintain a high phosphate soil test.

Comment (J. Karlovsky): I agree with Dr Saunders that phosphate should be applied in one single autumn application if the aim is to increase pasture production during the critical late autumn and winter period.

Concerning potash, in Waikato single applications have proved to be as effective as split applications and best seasonal distribution of response has been obtained with autumn applications. Autumn application gave 40 per cent of annual response in autumn and winter but spring applications gave only 20 per cent of annual response in this period. Application of a single dressing in late spring - early-summer as suggested by Mr During gave 30 per cent of annual response for Waikato in autumn and winter.

Residual effect of phosphate topdressing appears to vary from soil to soil in Waikato.

Comment (Saunders): It is very probable that the residual effect should. vary from soil to soil and I have drawn attention at the end of my paper to two factors, the ratio of aluminium-bound to iron-bound phosphate and build-up of organic phosphorus, which may influence the residual effect.

Chairman's Comments (T. W. Walker): There is clearly a great deal more of this type of work to be done to rationalise our fertiliser usage.