Response to re-application of phosphate fertilisers on hill pasture where fertiliser had been withheld for seven years

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Abstract

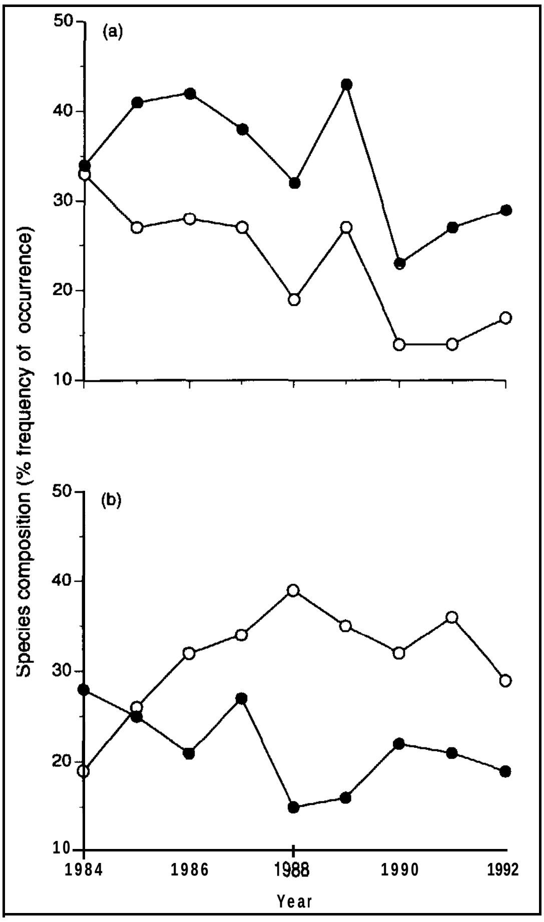
A field experiment at the AgResearch Te Kuiti Research Area examined effects of re-application of phosphorus (P) fertilisers on production and composition of hill pastures (1520% slope) which had received no P for 7 years. Treatments were 0, 20, 40 and 80 kg P/ha/year as single superphosphate (SSP) or North Carolina reactive phosphate rock (RPR). The soil was a yellow-brown earth/yellow-brown loam intergrade with Olsen P 9. Re-application of P produced a rapid and large increase in pasture production of up to 42 and 61% in years 1 and 2, respectively, and brought production up to 95% of that measured in neighbouring regularly fertilised paddocks. The pasture response to RPR was less (P<0.01) than that to SSP in both years, particularly at the highest rate. This indicated that RPR was less suitable for capital application. The P response was due almost entirely to an increase in white clover growth, and N_2 fixation was estimated to increase from 30 to 130 kg N/ha/year. In year 2, there was an increase in ryegrass content of pasture receiving the high P rate and this was attributed to increased nitrogen availability due to increased N_2 fixation.

Keywords: hill country, phosphorus, reactive phosphate rock, superphosphate

Introduction

During the past decade, fertiliser use on hill country has declined considerably and the soil phosphorus (P) status is generally low (Ledgard *et al.* 1991). Long-term grazing studies showed that withholding P fertiliser decreased pasture and animal production by up to 30% over 4-7 years (Lambert *et al.* 1990; O'Connor *et al.* 1990). In these studies there was a decline in white clover (e.g., Figure la) and ryegrass content in the pastures and an increase in browntop (e.g., Figure lb), weed and moss content. This deterioration in pasture species composition may restrict the ability of the pastures to respond to P. The aim of this experiment was to determine the effects of re-application of P fertilisers on pasture production and composition using a pasture where fertiliser had been withheld for 7 years.

Figure 1 Effect of withholding (0) or maintaining (●) fertiliser (superphosphate at 0 or 250 kg/ha/year) on (a) white clover and (b) browntop content of hill pasture (O'Connor *et al.* 1990; Ledgard unpublished).



Experimental

Site and soils

The experiment was located within paddocks of a long-term P grazing trial at the AgResearch Te Kuiti Research Area, described by O'Connor *et al.* (1990). Paddocks had a westerly to southerly aspect.

Soil in the experimental areas was a yellow-brown earth/yellow-brown loam intergrade with an average P retention of 80% and pH of 5.7. Average annual rainfall is 1500 mm,

Treatments

Four representative paddocks were selected within farmlets which had received either 0 or 250 kg/ha/year of superphosphate (SSP) in the previous 7 years. Within each paddock, a uniform site of 15-20° slope was fenced off to exclude grazing animals.

In the regularly fertilised paddocks, treatments were 0 and 20 kg P/ha as SSP and were replicated 4 times at each site. In the unfertilised paddocks, treatments were 0, 20, 40 and 80 kg P/ha/year as SSP (220, 440 and 880 kg/ha/year) or North Carolina reactive phosphate rock (RPR at 150, 300 and 600 kg/ha/year) and there were 4 replicates. SSP contained 9.1% total P, 8.1% citric-soluble P and 7.6% water-soluble P, and RPR contained 13.1% total P and 4.0% citric-soluble P.

All plots (5 m x 1 m) received basal applications of sulphate-sulphur, potassium (K) and trace elements to ensure that P was the only limiting nutrient. Sulphur was re-applied at 6-monthly intervals (30 kg S/ha) and K at 3-monthly intervals (50 kg K/ha).

A uniformity harvest was taken prior to application of treatments on 23 May 1990 and treatments were re-applied one year later.

Measurements

Pasture production was measured by regular cutting with a lawn mower and 50% of clippings were returned. In the unfertilised paddocks, pasture species composition was determined by botanical separation of pasture from each plot at each harvest. In the regularly fertilised paddocks, pasture species composition was determined in autumn 1991 and in summer 1992.

Soil samples were collected initially and at the end of the 2-year measurement period for analysis of Olsen P by AgResearch Soil Fertility Service.

Results

Pasture production

Unfertilised paddocks

A rapid pasture response to re-application of SSP was evident at the first harvest in late winter, whereas there was no response to RPR by this harvest (Figure 2). After 1 year, there was a large response to SSP, which increased with increasing P rate and was 42% at 80 kg PI ha. In contrast, the pattern of response to increasing rate of RPR was flatter than to SSP and the increase in yield to RPR at 80 kg P/ha was 16%.

In year 2, there was a similar pattern of response to that in year 1 but it was larger, being up to 61% at 80 kg P/ha as SSP (Figure 3). The relative response to RPR increased in year 2 and the response to 80 kg P/ha as RPR was 33%.

Figure 2 Effects of re-application of P fertilisers on pasture production at the first harvest and after one year. Bars represent LSD (5%).

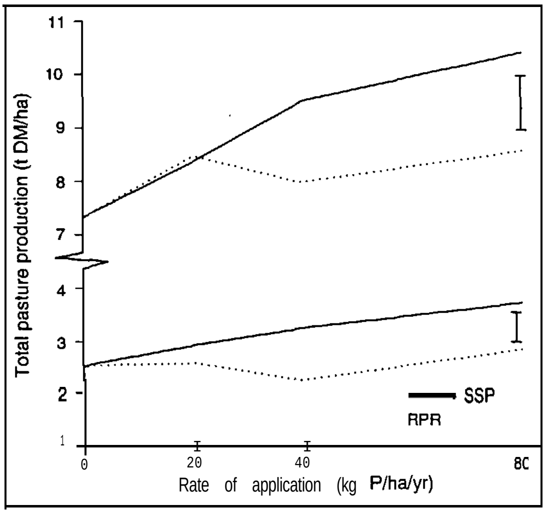
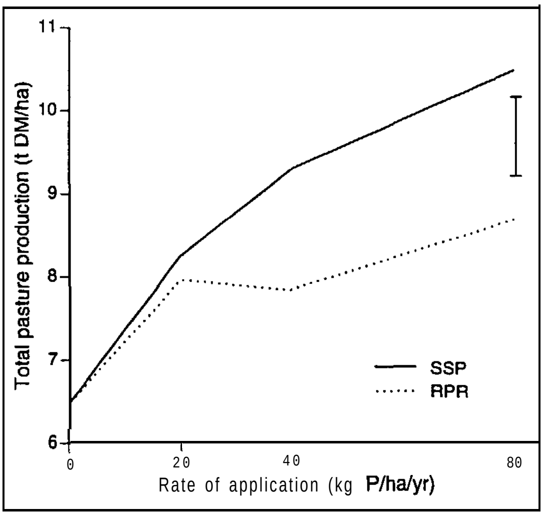


Figure 3 Effects of re-application of P fertilisers on pasture production in year 2. The bar represents LSD (5%).



Regularly fertilised paddocks

At one harvest in the first year, cattle broke into plots in one of the paddocks and therefore an annual yield could not be calculated. However, based on all data available, there was no significant difference in yield between the 0 and 20 kg P/ha treatments. In year 2, pasture production was 9535 and 10286 kg DM/ha (LSD (5%) = 2050) for the 0 and 20 kg P/ha treatments respectively.

Pasture species composition

Unfertilised paddocks

In year 1, there was no significant effect of fertiliser on the yield of individual pasture species, except for white clover where there was a large response to P (Figure 4a). The response by white clover was significantly (P<0.01) lower for RPR than for SSP in both years (Figures 4a and b). In year 2, there was no significant effect of fertilisers on the yield of other species,, except for ryegrass where there was an increase at the highest rate of SSP application (Figure 5).

Regularly fertilised paddocks

Pasture species composition was measured at harvests in autumn 1991 and summer 1992 and in both cases there was no significant difference between the 0 and 20 kg P/ha treatments. The most obvious difference in composition between pastures in unfertilised and regularly fertilised paddocks was a higher (about 2- to 3-fold) proportion of ryegrass in the latter (Table 1).

Olsen P soil test

In autumn 1990 (prior to application of treatments), the Olsen P soil tests averaged 9 and 14 in the unfertilised and regularly fertilised paddocks respectively.

By autumn 1992, application of fertiliser had significantly increased Olsen P tests in the unfertilised paddocks (Table 2). On average, the increase in Olsen P from RPR application was only 29% of the increase from SSP application.

Table 1 Pasture species composition (% by dry weight) measured on 12 December 1992.

	Ryegrass	Srowntop	Other grasses[a]	White clover	Weeds
Unfertilised paddocks:					
0 P	8	5	44	13	29
20 kg P/ha (SSP)	6	3	34	33	24
80 kg P/ha (SSP)	11	4	27	43	15
LSD (5%)	6	2	18	6	14
Regularly fertilised paddocks:					
0 P	19	3	29	27	22
20 kg P/ha (SSP)	26	1	25	27	21
LSD (5%)	16	4	17	10	10

[a] *Anthoxanthum oderatum, Cynosurus cristatus, Holcus lanatus* and Pm species

Table2 Effect of fertiliser application on Olsen P soil test, two years after commencing the experiment.

	kg P/ha/year				
	0	20	40	80	LSD (5%)
SSP	6.0	10.0	14.0	25.7	2.2
RPR		9.7	6.7	13.0	

Figure 4 Effects of re-application of P fertilisers on clover production in (a) year 1 and (b) year 2. Bars represent LSD (5%).

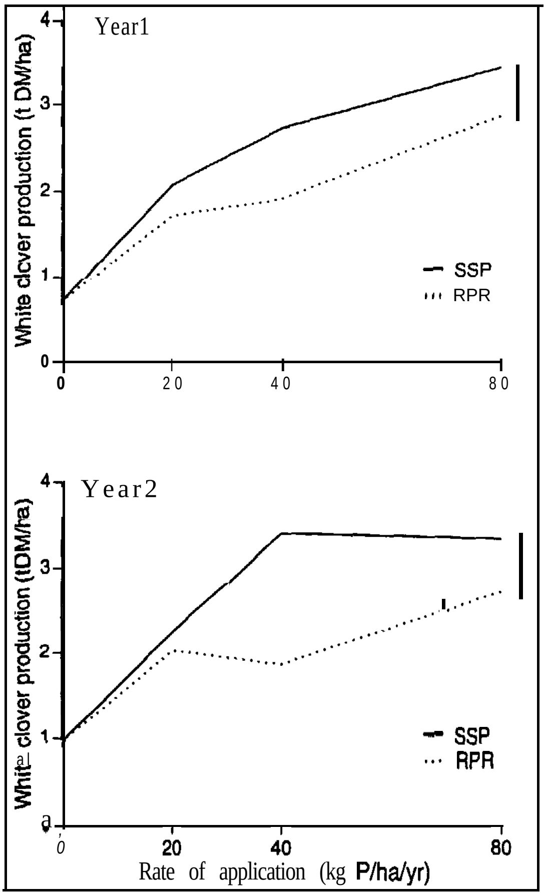
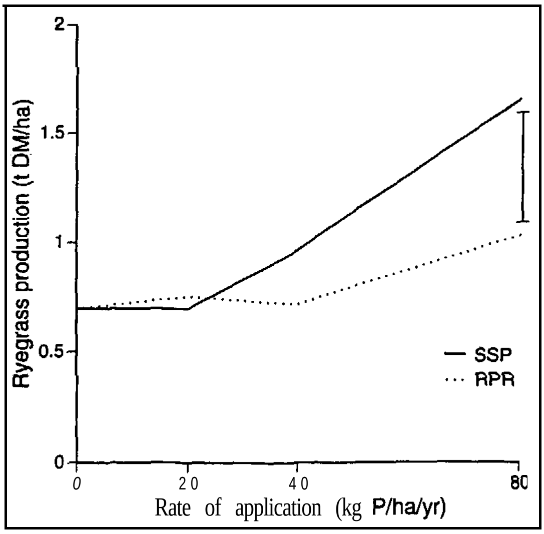


Figure 5 Effects of re-application of P fertilisers on ryegrass production in year 2. The bar represents LSD (5%).



Discussion

During 7 years without P fertiliser, pasture production had declined by about 30% and pasture species composition deteriorated as evidenced by a large decline in white clover content (Figure la). Despite this species deterioration, the pastures showed a rapid and large response to reapplication of P fertiliser. By the second year, pasture production from the 'capital' SSP treatment (80 kg P/ha/year) was 95% of that in the regularly fertilised paddocks.

The rapidity and size of the pasture response to P re-application will depend on the previous fertiliser history (base soil fertility status) and the extent of pasture deterioration after withholding fertiliser. Lambert et al. (1990) measured little response to P re-application on pastures with a poor P fertiliser history and a much larger response on neighbouring pastures with a better P history. Similarly, Edmeades *et* al. (1984) measured a much slower increase in pasture growth to P application on a reverted browntop-dominant pasture with a low legume content compared with a pasture with mainly white clover and ryegrass. In our experiment, the unfertilised pastures had been grazed at a relatively high stocking rate (11-14 ewes/ha) and this will have slowed the reversion to poor-quality species (Sheath et *al.* 1988).

The increase in pasture production with increasing rate of SSP application showed a typical diminishing returns pattern (Figures 2 and 3). However, the unfertilised paddocks were highly responsive, as evident from the 10% increase in production from 40 kg P/ha to 80 kg P/ha as SSP in both years. In contrast, when P was withheld in the regularly fertilised paddocks there was no significant effect on production. Similarly, Sinclair et al. (1990) showed little initial response to P fertiliser on regularly fertilised pastures. Thus, the large responses measured in the unfertilised pastures were more comparable with those obtained in a pasture development programme, given that the sward contained responsive species (e.g., Nguyen et *al.* 1989).

The response to RPR was significantly ($P<0.01$) less than that to SSP (average relative response of 47 and 58% in years 1 and 2 respectively). In year 1, this was most evident at higher rates of application where there was little extra response to RPR in contrast to the increasing response from high rates of SSP. The latter was also measured in a national series of P fertiliser trials (Sinclair et *al.* 1990). This indicates that where capital application of fertiliser is to be applied after a number of years without fertiliser, a soluble P form (e.g., SSP) is most effective in providing a rapid improvement in pasture production. However, where severe reversion of pasture species has occurred and a slow improvement in pasture production and species composition is expected, the form of P fertiliser may be unimportant (Lambert *et* al. 1990).

Virtually all of the response to P re-application occurred from increased growth of white clover (by over 3-fold). This has important implications for inputs of nitrogen (N) through symbiotic N_2 fixation. From the research of Ledgard *et al.* (1987) it can be estimated that N_2 fixation by white clover in the 0 and 80 kg P/ha/year (SSP) treatments was approximately 30 and 130 kg N/ha/year respectively in both years 1 and 2. This decrease in N inputs may be an important factor affecting the persistence of ryegrass, which is a high N-demanding species (Andrew & Johansen 1978). Pastures in the unfertilised paddocks had a lower ryegrass content than those in the regularly fertilised paddocks (e.g., 8 v. 26% of dry weight respectively), presumably reflecting reduced N inputs from N_2 fixation due to less clover growth in the previous 7 years (Figure la). The grazing experiments of Gillingham *et al.* (1990) and Lambert *et al.* (1990) also showed reduced ryegrass content in pastures where P fertiliser had been withheld.

Re-application of P had no effect on ryegrass production in year 1, but by year 2 an increase in ryegrass growth was evident in the 80 kg P/ha treatments. This probably reflected increased N_2 fixation by white clover and the transfer of fixed N to grasses via mineralisation of N from senesced clover shoots, roots and nodules and from the pasture clippings returned to simulate N recycling in excreta from grazing animals. This 'underground transfer' of N is a relatively slow process, about 2-26% of legume N being utilised by grasses within one year (Ledgard & Steele 1992). Thus, the process of increasing ryegrass at the expense of other 'low-fertility-tolerant' grasses, in conjunction with good grazing management, is likely to take a number of years.

Conclusions

Withholding P fertiliser from regularly topdressed hill pastures for 7 years decreased pasture production by about 30% and caused reversion of pasture species, with much less white clover and ryegrass. Re-application of P produced a rapid and large response in pasture production which was evident almost entirely through an increase in white clover growth.

A capital application of 80 kg P/ha/year as SSP increased total production to near that from a regularly fertilised pasture within 2 years. RPR produced little extra response in pasture growth at high rates of application and appeared less suitable than soluble P (e.g., SSP) for capital application.

The increased white clover growth was estimated to increase N_2 fixation from 30 to 130 kg N/ha/year. In year 2, there was some increase in ryegrass content in pasture receiving the high P rate, probably due to increased N availability via greater N_2 fixation.

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