Fertiliser requirements of Russell lupins

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Abstract

Russell lupins were established by overdrilling into depleted tussock high country at Mesopotamia Station, South Canterbury, New Zealand, in September 1990. The soil was low in phosphate and sulphur, as well as being deficient in boron and molybdenum. Phosphate was applied at four rates (0, 12.5, 25 and 50 kg P/ha) as either Carolina rock phosphate or triple superphosphate and sulphur was applied at 0 or 60 kg S/ha. In the absence of sulphur, lupins survived for three years but did not produce significant growth. In the presence of sulphur there was a marked response to added P in dry matter production. In the second growing season (1991), lupins responded more to the readily available triple phosphate than to the rock phosphate, while in the third (1992) and fourth (1993) seasons the response to P was greater with the rock phosphate. The greater lupin production with triple phosphate in the first two seasons resulted in significantly more grass production from these plots by the fourth season. *Hieracium* growth was reduced by competition from lupins and grass.

Additional key words: Lupinus polyphyllus, *rock phosphate, triple phosphate, sulphur, high country,* Hieracium pilosella.

Introduction

Research attention is being directed towards more nutrient-efficient legumes as alternatives to white clover for high country pastures of the South Island. Russell lupin (*Lupinus polyphyllus* Lindl.) has received considerable interest because of its ability to grow and spread naturally on unfertilised tussock grassland sites (Scott, 1993). It will grow on acid, low phosphate soils and is known to tolerate high levels of soluble aluminium (Davis, 1981). Scott and Covacevich (1987) found that Russell lupin was the outstanding legume in a mixture of 23 pasture species sown at Mt John, Lake Tekapo. They concluded that this species could have a major role as a grazing legume on lower fertility high country sites. Russell lupin is known to grow well and fix nitrogen on soils that are severely P deficient for common pasture legumes (Davis, 1991; Svavarsdottir, White and Palmer, 1994) but little is known of its sulphur requirements or the effects of various forms of P fertiliser on its growth.

In a pot trial, with a Cass soil from Mesopotamia station, Miller (1989) found that Russell lupin did not respond to lime and was able to utilise rock phosphate very effectively. In order to investigate the nutritional needs of Russell lupin further, we established a field experiment at Mesopotamia with the aim of evaluating the ability of this lupin to utilise phosphorus as triple superphosphate or rock phosphate in the presence or absence of sulphur. In addition the ability of lupin to compete with mouse-ear hawkweed (*Hieracium pilosella* L.) was measured.

Materials and Methods

A field experiment was established at Mesopotamia Station, South Canterbury on an upland yellow-brown earth known to be deficient in sulphur (S, SO_4 = 2 ppm), phosphorus (P, Olsen P = 6) and molybdenum (Mo). The site was depleted fescue tussock grassland (*Festuca novae-zelandiae* (Hack.) Ckn.) dominated by brown top (*Agrostis capillaris* L.), sweet vernal (*Anthoxanthum odoratum* L.) and mouse-ear hawkweed (*Hieracium pilosella* L.), with considerable bare ground. Annual rainfall is 940 mm and the altitude is 500 m above sea level.

Russell lupin cv. Connie seed was over-drilled on 10 September 1990 using a small plot drill with a single disc followed by a hoe coulter, making a 2 cm deep slot. Seed was scarified and inoculated with the specific Rhizobium strain (WU 425) before sowing and drilled in 30 cm rows at a rate designed to provide 50 plants/m^2. Following overdrilling, 2m x 10m plots were pegged out across the drill rows. Triple superphosphate (21 % P) and North Carolina rock phosphate (13 % P) were each broadcast at 0, 12.5, 25 or 50 kg P/ha, and elemental sulphur applied at 0 or 40 kg S/ha in a factorial experiment with four replicates. A further 20 kg S/ha was applied as gypsum to all sulphur plots on 2 October 1991. Basal Mo was applied at sowing (250g sodium molybdate/ha) and basal boron (B, 5kg borax/ha) one year later when some B deficiency became evident.

Plant establishment was measured on 7 December 1990 and 18 March 1991 in 1 m^2 quadrats randomly placed in each plot. On 17 December 1991 all plots were scored by two pairs of observers on a 1-10 scale for dry matter yield as follows: 1 = very small red/yellow lupin seedlings 30-40 mm high, 2 = larger seedlings but still chlorotic, up to 150 mm high, 4 = green lupins, low mass, 700 kg/ha, 6 = mass 2100 kg/ha, 8 = 3500 kg/ha, 10 = 5000 kg/ha. At the same time, vegetation cover in the lupin plots was estimated in the following categories: grass (browntop and sweet vernal), lupin, mouse-ear hawkweed, white clover *(Trifolium repens* L.)(resident) and volunteer seedlings of broom (*Cytisus scoparius* (L.) Link).

On 14 December 1992, two 0.20 m^2 quadrats were cut to 50 mm stubble height across three lupin rows in each plot, and bulked, separated into lupin and grass, dried and weighed. Following these measurements the plots were grazed hard with 300 merino sheep for 24 hours.

On 16 December 1993, dry matter yields were obtained using the same method as in 1992. Both grass and lupin material was analysed for P, S and nitrogen, (N) for all plots of 2 of the 4 replicates.

Analysis of variance was performed on log transformed data (as the non transformed data were not normally distributed) and these were back transformed for presentation in the graphs.

Results

Establishment of Russell lupins was excellent, with about 50 plants/m^2 present in December 1990, and little change in the following March. Responses to sulphur and to triple superphosphate were evident in the lupins within three months of sowing, and within six months the response to S was marked in the presence of phosphate with triple superphosphate superior to rock phosphate. By December 1991, during the second growing season, these responses were very strongly shown (Fig. 1). Lupin growth was extremely poor without added S. Those plots receiving P alone were not significantly different from the control plots. There was a response to sulphur alone and a major response to P in the presence of S up to the highest rate used, with triple superphosphate being significantly better than rock phosphate. Maximum lupin yield was 2800 kg DM/ha (converted from scores) from the 50 kg P/ha rate of triple superphosphate plus S treatment. Lupins in the best plots were in flower, but at lower P levels they remained vegetative. The vigorous lupin growth suppressed production of mouse-ear hawkweed as measured by the vegetation ranking (White *et al.*, unpublished). Broom also responded to the fertiliser treatments but was subsequently grubbed from the plots.

Figure 2 shows the dry matter yields of Russell lupin measured on 14 December 1992 in the third season. Without sulphur, lupins failed to produce any appreciable dry matter, whatever the form or level of applied P, although some plants from the original sowing were still surviving after three years. Lupins grew reasonably well with S alone and produced over 2,000 kg DM/ha at the 1992 harvest. The marked response to P in the presence of S continued, with more than 6,000 kg DM/ha from the best plots. In contrast to the 1991 measurements in the second season, rock P was significantly better than triple P as a source of phosphate. Grass growth in 1992 was observed to be more vigorous with triple P than with rock P (Fig 2).

The mob grazing by sheep,following the 1992 harvest appeared to cause a significant death of lupin plants. The lower lupin population was a major reason for overall lower yields in 1993 (Table 1). The response to sulphur alone in December 1993, in the fourth season, was greater than in 1991 or 1992. While rock P was still

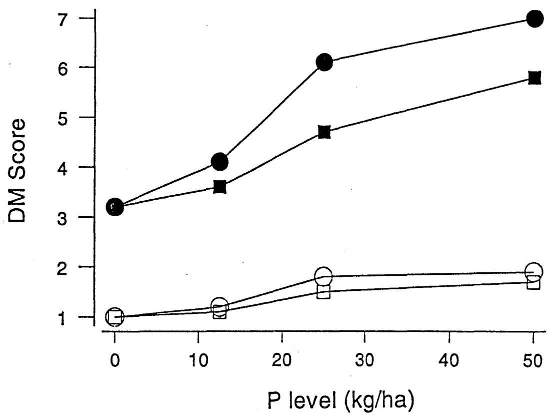

Figure 1. Effect of rates of phosphorus and sulphur on dry matter scores of lupins in the second growing season, in December 1991. Circles = Triple phosphate; Squares =Carolina rock phosphate; Solid symbols = plus S; Open symbols = minus S.

superior to triple P, the positive response in lupin DM to P in the presence of S had completely disappeared. In fact there was an overall decrease in lupin DM/ha with increase in P level.

In December 1993, when both lupin and grass components were measured, Table 1 shows that there was a strong response in browntop and sweet vernal production where vigorous lupin growth had occurred previously. With lupins at the highest P level there was a significantly greater grass yield in the triple super than in the rock P treatment.

Chemical analyses of plant material harvested in December 1993 showed that N% in lupin was higher than in the grass but that N% did not respond to P level (Table 1). Nitrogen yields (Table 1) indicate that more nitrogen had been transferred to the grass in the plots with triple P than with rock P, and that there was a pronounced response to P level. This was offset by the decrease in N yield in the lupins in response to increased P level (Table 1.).

Discussion

The experiment clearly demonstrated that Russell lupin cannot be grown successfully on sulphur-deficient soils without sulphur fertiliser. On this site which is acutely sulphur deficient, the lupins, in those plots which lacked sulphur, grew little better than control plots. Once sulphur was applied, the lupin growth improved over time until, in 1993, sulphur-alone treatments were comparable with, or better than, those receiving S and P. Phosphate fertiliser was less important, except for the lupin establishment, as demonstrated in the first three seasons when addition of P provided much improved growth. This large positive response of the lupins to the P that was applied at sowing time, and which disappeared in the fourth year (1993), lends support to the theory that lupins are able to obtain greater supplies of soil P over time. This could be caused either by the progressive development of a larger, deeper root system, or, perhaps, to formation of proteoid roots, known to form on some species of lupin and which are known to exude citric acid to dissolve soil phosphates which the plants then absorb (Dinkelater *et al.*, 1989). However, no proteoid roots were observed on the lupins in this trial although their presence was not systematically investigated.

Triple superphosphate was superior in the first two years, presumably due to the greater availability of the

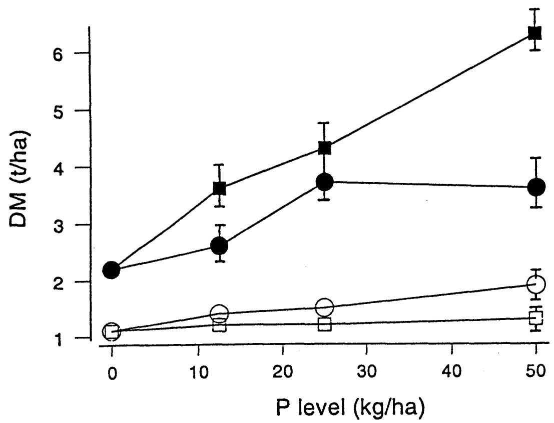

Figure 2. Effect of rates of phosphorus on dry matter yield of lupin (solid symbols) and grass (open symbols) in the plus S treatments in the third growing season, in December 1992. Circles = Triple phosphate; Squares = Carolina rock phosphate. Error bars represent standard errors of the means.

Table 1. Dry matter (DM), herbage nitrogen (%N) and nitrogen yield (N yield) of lupin and grass from the fourth season, in December 1993, grown with different levels of rock (RP) and triple (TP) phosphate for the plus sulphur treatments only.

		Level of phosphate (kg P/ha)			
		P0	P1	P2	P3
		0	12.5	25	50
Lupin					
RP	DM (t/ha)	1.83	1.97	1.04	1.07
	% N	1.86	1.62	1.53	1.42
	N yield (kg/ha)	34.0	31.9	15.9	15.2
TP	DM (t/ha)	1.83	1.17	0.94	0.56
	% N	1.86	1.85	1.51	1.65
	N yield (kg/ha)	34.0	21.6	14.2	9.2
Grass					
RP	DM (t/ha)	1.70	2.18	2.40	2.70
	% N	1.20	1.23	1.12	1.25
	N yield (kg/ha)	20.4	26.8	26.9	33.8
	DM (t/ha)	1.70	2.42	2.84	3.49
	% N	1.20	1.29	1.27	1.28
	N yield (kg/ha)	20.4	31.2	36.1	44.7

mono-calcic P, but the North Carolina rock phosphate gave a greater response in the third growing season (1992), supporting the findings of Miller (1989). Where rainfall is 800 mm or greater, triple P may be replaced partly or wholly by the less soluble rock phosphate but in lower rainfall areas the more soluble form of P may be best (Bolan *et al.*, 1990).

The good response by lupins to sulphur alone is in contrast to results from an adjacent white clover experiment where both S and P were required before good growth of clover occurred (Jarvis *et al.*, unpublished).

Nitrogen fixed by Russell lupin caused a large increase in the growth of resident browntop and sweet vernal grasses. The greater response in lupin growth to triple phosphate in the second growing season (1991) resulted in the most grass production occurring in the highest triple P and S plots by the fourth year. The rapid exploitation of increased soil N by grasses such as browntop and the suppression of legume cover may have been hastened by the annual hard grazing management. In contrast Scott and Covacevich (1987) reported that lupins remained dominant after four years under more frequent grazing at low stocking rates. This would indicate that it is important to have a less extreme type of stock management for lupin survival and to avoid the buildup of rather unpalatable grasses such as browntop and sweet vernal.

Mouse-ear hawkweed, a major component of the original vegetation, was reduced substantially by the tall-growing lupins, an effect also observed by Svavarsdottir *et al.* (1994). This is likely to be a shading effect, as this species of hawkweed does not tolerate strong competition for light (Scott, 1984; Treskonova, 1991). The form of those plants which remained was much more erect, making the plant more accessible to grazing animals. Subsequent grass dominance also suppressed hawkweed under the one hard grazing per year regime.

By the fourth season all lupin plots were showing distinct symptoms of sulphur deficiency and further sulphur was applied in May 1994. The experiment will continue for a further three years to investigate further the S response to this additional fertiliser.

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