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PERFORMANCE OF ELEMENTAL SULPHUR, SULPHUR-SUPERPHOSPHATE AND SUPERPHOSPHATE ON DRY INLAND SOUTH ISLAND HILL COUNTRY

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Abstract

Four trials were established on sunny and shady slopes at two altitudes in S-deficient dry inland hill country in North Otago, to compare the effectiveness of three commercial S fertilisers – elemental S, "wet-mix" S-superphosphate, and superphosphate – during the legume establishment phase of pasture development. The effects of single initial applications of these fertilisers were followed by harvesting legumes over three years.

All sites were severely deficient in S but showed variable response to P; no P responses being recorded on the steeper, higher altitude sites. In terms of DM response per kg S applied superphosphate was slightly more effective than S-superphosphate and both were markedly more effective than elemental S over the 3-year period. Aspect had little *or* no influence on relative P and S requirements or fertiliser effectiveness.

Responses to elemental S were approximately linear up to 100 kg S/ha, and application of lesser rates of elemental S are not recommended. On the basis of DM produced per weight of applied fertiliser, "wet-mix" S-superphosphate was superior to superphosphate, and about 200 kg/ha S-superphosphate is suggested as a minimum initial application rate for legume introduction on these soils (yellow-grey earths). An initial dressing at this rate maintained around 70% of potential yield over the 3 year trial period.

Keywords: elemental S, Ssuperphosphate, hill soils, yellow-grey earths, legume establishment, fertiliser, sulphur

INTRODUCTION

Sulphur-deficient hilly and steep soils that are developed on schist or greywacke with minor loess, and which experience a seasonal moisture deficit which limits pasture production in most years, cover 650 000 ha of the South Island, from Southland to Marlborough. These soils belong to the yellow-grey earth soil group and to the intergrades between the yellow-grey earths and yellow-brown earths (N.Z. Soil Bureau 1968).

Without oversowing and topdressing, dry matter (DM) production on these soils, from indigenous vegetation such as silver tussock, hard tussock, annual grasses, suckling clover and haresfoot trefoil, can be as low as 400 kg/ha/yr. Introduced legumes show variable responses to phosphorus (P), sulphur (S) and'molybdenum (Mo) (O'Connor 1962; Ludecke 1966; Ludecke and Leamy 1972; Douglas and Kinder 1975; Douglas and Risk 1981) and with oversowing and adequate fertiliser the soils will produce an average of 6000 kg DM/ha/yr with up to 17 000 kg DM/ha in exceptionally wet years (McLeod 1974).

In establishing legume-based pastures on these soils an effective sulphur fertiliser must be applied as virtually no growth is achieved without S. The main commercial alternatives are agricultural grade elemental S, S-super-

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phosphate and superphosphate, with % S/P contents of approximately 100/0, 26/7 or 18/8, and 10/9 respectively. Because of explosive hazards elemental S may not be applied on its own from fixed-wing aircraft but it has been applied by helicopters. The suitability of these fertilisers is likely to differ in different situations because (a) the relative requirements for S and P may differ, and (b) the effectiveness of the S component of the fertilisers depends heavily on environment. The second effect arises because the different fertilisers contain S in different chemical and physical forms. In superphosphate it is in the sulphate form which is immediately available to plants but also susceptible to leaching loss. S-superphosphate contains both sulphate-S and elemental S; the latter is slowly converted to sulphate by soil micro-organisms. This biological process can proceed at an agronomically effective rate only when the soil is moist and warm and when the S is in finely divided form. When S-superphosphate is made by the "wet-mix" process, which involves adding molten S to superphosphate during its manufacture, the elemental S in the final product is much more finely divided than S in agricultural grade elemental S. In relatively dry conditions where leaching of sulphate is not a significant problem, sulphateS is markedly more effective (per kg of S applied) than elemental S (Ludecke 1965). "Wet-mix" S-superphosphate, with its finely divided elemental S, and some sulphate-S, should perform much better than agricultural elemental S. However, this product has never been rigorously compared with superphosphate and elemental S in the dry hill country environment.

The purpose of the work described here was to compare these three fertilisers for legume establishment on a range of S-deficient soils for which they might be considered practical alternatives.

METHODS AND MATERIALS

Four trials were laid down on sunny and shady aspects of a ridge, at two altitudes, on Glencairn station (rainfall 600-700mm) west of Lake Benmore at the southern margin of the Mackenzie Basin. A summary of trial site characteristics is given in Table 1. Detailed soil and site information is given by McIntosh et *al.* (1981). None of the sites had been previously oversown or topdressed.

At each site agricultural- grade elemental S, "wet-mix" S-superphosphate and superphosphate were spread at 4 rates of S; 0, 25, 50 and 100 kg/ha at the beginning of the experiment. Properties of the fertilisers are recorded in Table 2. So that the effectiveness of the S components of the different fertilisers could be compared additional treatments were included in which the above rates of S fertiliser were supplemented with annual applications of P to bring minimum P application rate up to 40 kg P/ha/yr. To gauge the performance of the fertilisers against yields from plots receiving "adequate" S and P, "high SP" controls receiving 25 kg S/ha as gypsum plus 25 kg S/ha as elemental S, applied twice yearly, together with 40 kg P/ha/yr were also included, Sodium molybdate (200 g/ha) was applied to all plots.

Plots were oversown with a mixture of Wairau lucerne at 40 kg/ha and 4 kg/ha each of "Grasslands Huia" white clover (*Trifolium repens* L.), "Grasslands Pawera" red clover (*T. pratense* L.) and alsike clover (*Trifolium hybridurn).* Seeds were inoculated and lime coated. The high seeding rates were designed to give good establishment of seedlings in the first year of the experiment so that fertiliser responses would not be limited by inadequate ground cover.

Table 1: CHARACTERISTICS OF TRIAL SITES, GLENCAIRN. SOIL NAMES ARE PROVISIONAL ONLY (see McIntosh et *al.* 1981). CHEMICAL ANALYSES REFER TO TOP 7.5cm OF SOIL. OLSEN P UNITS ARE APPROXIMATE AS VOLUMETRIC METHOD USED.

Altitude	Shady Aspect	Sunny Aspect
800 m	**Trial D** Olsen P = 25 μg/g P retention = 14% pH = 6.2 Phosphate-extractable = 2 μg/g SO_4 Vegetation = hard tussock; sweet vernal Soil Mapping Unit = Cuthbert steepland soil (subhygrous yellow-grey earth)	Trial C Olsen P = 24 μg/g P retention = 11% pH = 6.5 Phosphate-extractable = 2 μg/g SO_4 Vegetation = matagouri, scabweed, silver tussock mulleins Soil Mapping Unit = Omarama steepland soil (dry-subhygrous yellow-grey earth)
450 m	Trial B Olsen P = 15 μg/g P retention = 20% pH = 6.3 Phosphate-extractable = 2 μg/g SO_4 Vegetation = hard tussock, sweet vernal *Bromus* and *Notodanthonia* Soil Mapping Unit = Meyer hill soil (dry-subhygrous yellow-grey earth)	**Trial A** Olsen P = 9 μg/g P retention = 10% pH = 6.3 Phosphate-extractable = 2 μg/g SO_4 Vegetation = scabweed, Silver tussock, *Bromus* and *Notodanthonia* Soil Mapping Unit = Meyer soil (dry-subhygrous yellow-grey earth)

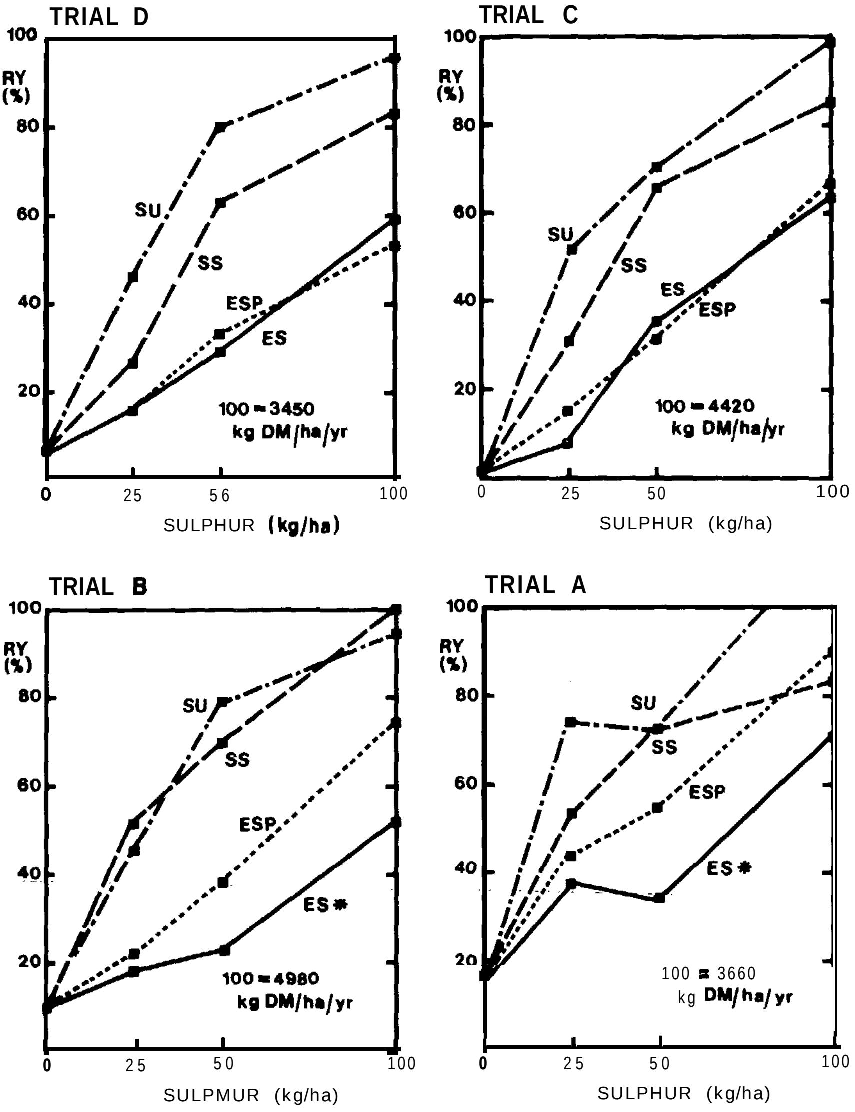

Figure 1. Trials A, B, C and D, Glencairn: mean annual DM over 3 years, relative to yield obtained on high SP treatments. ES = elemental S; SS = S-superphosphate; SU = superphosphate. ESP = elemental S + annual additions of 40 kg P/ha. *indicates significant response to additional P obtained ($P<0.05$). No responses to additional P were obtained for S-superphosphate or superphosphate at any site.

Table 2: PROPERTIES OF S FERTILISERS USED.

Fertiliser	Superphosphate	Wet-mix S-superphosphate	Elemental S
% SO_4-S	10	7	0
% elemental S	0	20	100
% total S	10	27	100
% of elemental S which:			
passes 1.2mm screen	-	99*	88
passes 0.5mm screen	-	97	48
passes 0.3mm screen	-	92	35
passes 0.15mm screen	-	63	20
% total P	9	7	0
Weight (kg) required for 100 kg total S	1000	370	100

* To determine the particle size of elemental S in S-superphosphate the superphosphate component is dissolved out with dilute acids and the residual elemental S is sized on standard screens.

RESULTS AND DISCUSSION

DM yields over the 3 year period, expressed as a percentage of DM yield from the high SP plots, are shown in Fig. 1 (separate trials) and Fig. 2 (mean of all trials). DM consisted predominantly of lucerne on sunny sites and approximately equal proportions of lucerne and clover on shady sites. All four sites were extremely responsive to sulphur, as could be expected from the very low soil sulphate contents in topsoils (Table 1) and subsoils (McIntosh *et al.* 1981). Legumes on the lower altitude sites responded to P, but not on the steeper, higher altitude sites. Again, responsiveness was in accord with soil test values (Table 1). In contrast, aspect did not appear to affect site responsiveness to P and S.

In terms of DM response per kg of S applied, superphosphate was more effective than S-superphosphate at sites A,C, and D ($P<0.05$) but there was no difference at site B. At all sites elemental Sulphur was significantly ($P<0.05$) and markedly inferior to both superphosphate and S-superphosphate. This inferiority was reduced but not eliminated in the presence of added P at the two P deficient sites.

A measure of the comparative effectiveness of the fertilisers can be obtained by observing the quantities required to give equivalent yields. For example, for all trials combined (Fig. 2), 60% of maximum yield required 33 kg S as superphosphate, 43 kg S as S-superphosphate and 100 kg S as elemental S applied alone (or 83 kg S as elemental S applied with P).

The choice of S fertiliser form and rate for soils such as these will depend on material and application costs. It is difficult to compare elemental S with the other fertilisers because it cannot be applied by fixed-wing aircraft and various difficulties have arisen with helicopter application. However, should it be used

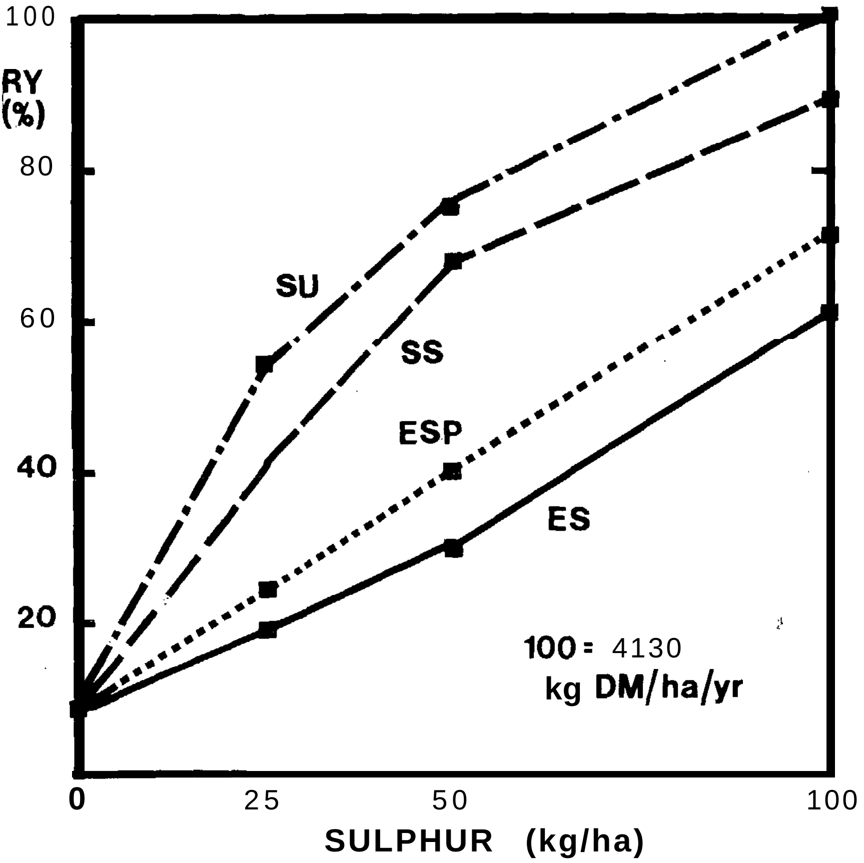

Figure 2. *Mean annual DM over 3 years, averaged over all sites. For other details see Figure 1.*

for legume establishment in a particle size similar to that employed in this experiment, application rates should not be much less than 100 kg/ha, otherwise yields will fall far short of potential. The virtual linearity of response up to 100 kg/ha elemental S provides good reason for applying that rate at least.

Although sulphur in S-superphosphate is slightly less effective than in superphosphate, economics very strongly favour S-superphosphate on those soils where P requirements are much less than S requirements.

Although the two low altitude sites gave significant responses to P when elemental S was used as the S fertiliser, no responses to P were obtained when the fertiliser was S-superphosphate, suggesting that the P content of S-superphosphate is adequate to meet P requirements of legumes on these soils.

Responses to S applied as S-superphosphate were approximately linear up to 50 kg S/ha, declining by various degrees above this rate. 50 kg S/ha produced about 70% of maximum yield. These considerations indicate 50 kg S applied in ca. 200 kg S-superphosphate to be a minimum initial application rate for legume introduction on these soils.

Rainfall at the closest climatological station to Glencairn (Tara Hills, 30 km to the southwest) was 24% higher than normal during the first growing season, close to normal in the second, and 18% less than normal in the third. Similar rainfall variation occurs frequently in the Mackenzie Basin. Although the moist first season, together with the high seeding rates used, undoubtedly boosted legume yields in the first year, there is no reason to suspect that the shape of the curves, on which the discussion above is based, has been markedly affected by unusual events (e.g. excessive leaching resulting from exceptional rainfall, or prolonged droughts hindering conversion of elemental S to available forms). The results can therefore be extrapolated with some confidence to similar seasonally dry S-deficient soils.

SUMMARY AND CONCLUSIONS

(1) Oversown legumes on yellow-grey earth soils in inland North Otago hill country responded strongly to S and showed a variable response to P. Soil tests gave a good indication of relative P and S deficiency.

(2) "Wet-mix" S-superphosphate was almost as effective, per kg S applied, as superphosphate. This demonstrates that the finely divided elemental S content of this material is an effective sulphur fertiliser even on relatively dry soils.

(3) S-superphosphate was superior to superphosphate on the basis of weight of DM produced per kilogram of fertiliser applied, and has a clear economic advantage. About 200 kg/ha S-superphosphate is suggested as a minimum initial application rate for legume introduction on these soils. An initial dressing at this rate maintained around 70% of maximum yield for 3 years.

(4) In terms of DM response per kilogram of S applied, elemental S was on average less than half as effective as S-superphosphate. Responses to elemental S were near-linear, and rates less than about 100 kg/ha of elemental S are not recommended.

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