Sulphur responses by legumes on soils derived from granodiorite in south-east Queensland

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Abstract

Established legumes on soils derived from granodiorite responded more strongly to sulphur than to phosphorus. These soils cover some 2400 km^2 of the better grazing lands of the coastal Burnett region. Wynn cassia at one site (bicarbonate-extractable P 7 mg/kg; SO_4–S 2 mg/kg) responded to phosphorus only when sulphur was applied; shrubby stylos at the other site (soil P 5 mg/kg; SO_4–S 4 mg/kg) responded only to sulphur. Nitrogen concentration in leaf tips of cassia increased 30% (to 3.34% N) with P and S at 10 kg/ha, whereas that in stylo increased only 10% (to 2.45% N).

As the previously recommended application (55 kg/ha/yr single superphosphate) for native pasture/legumes was economically marginal, the use of sulphur-fortified super (45% S) at lower rates could prove attractive.

Resumen

Las leguminosas establecidas en suelos de origen granodiorite respondieron más fuertemente al azufre que al fósforo. Este tipo de suelo cubre 2400 km² de las mejores tierras de pastoreo de la región costera Burnett. En una de las localidades (suelos con: 7 mg/kg P extractable; 2 mg/kg de SO4-S), la cassia Wynn respondió al fósforo únicamente cuando se aplicó azufre. En otra localidad (suelos con: 5 mg/kg de P extractable; 4 mg/kg de SO4-S), los stylos arbustivos respondieron únicamente al azufre. La aplicación de 10 kg/ha de P y S causó un incremento de 30% en la concentración del nitrógeno (hasta 3.34% N) en las puntas de las hojas de cassia; sin embargo, tal incremento en stylo fue de solamente 30% (hasta 2.45% N).

Debido a que la tasa de aplicación recomendada (55 kg/ha/a de superfosfato simple) para las pasturas nativas/leguminosas fue económicamente marginal, el uso de niveles bajos de super azufre-fortificado (45% S) podría ser atractivo.

Introduction

Applying single superphosphate to pastures of the coastal Burnett region greatly boosts growth of forage legumes and weight gains of steers, but may give marginal economic returns.

Soils derived from granodiorite cover some 2455 km^2 and provide some of the best grazing land in the region (Figure 1); they are considered less deficient in phosphorus than those in a strip of coastal land where botulism is endemic. An early grazing trial on a granodiorite soil (Bisset and Marlowe 1974) assumed responses to high rates of superphosphate (1150 kg/ha over 5 years) were due to phosphorus. However in 1980, a grass-seed crop growing near the site of this old trial responded dramatically to sulphate of ammonia, after it had failed to respond to straight nitrogen and phosphorus fertiliser.

Two grazing trials (25 km apart) had been sown on soils derived from granodiorite, one with round-leafed cassia (*Cassia rotundifolia* cv. Wynn), the other with shrubby stylos (*Stylosanthes scabra*). When mineral concentrations in the foliage of both legumes were compared with standard values (eg. Andrew and Robins 1969; Andrew 1977; Gilbert and Shaw 1989), phosphorus seemed adequate and sulphur deficient. The responsiveness of cassia to additional nutrients was not known.

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Small-plot fertiliser trials were superimposed on the grazed, but unfertilised, native grass-legume paddocks to differentiate the responses of phosphorus and sulphur.

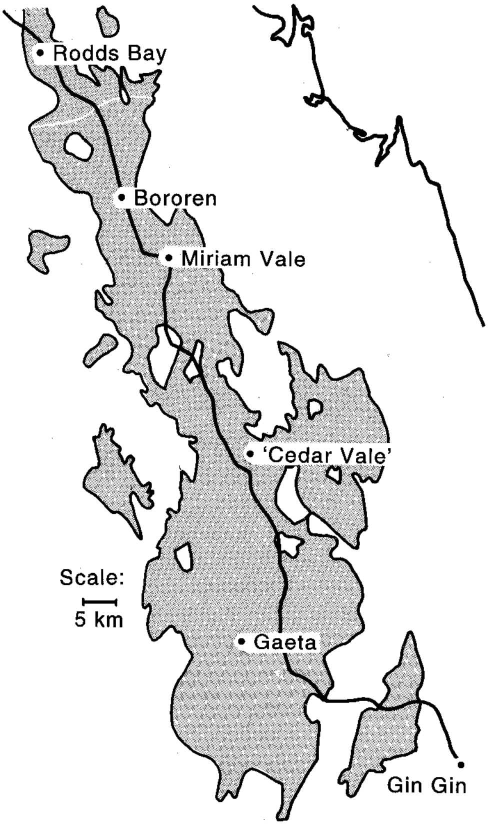

Figure 1. Area of soils derived from granodiorite in the coastal Burnett region of south-east Queensland.

Materials and methods

Sites

The cassia grazing trial was situated on the 'Lundsville' property (151°40'E, 25°50'S) near Gaeta, 40 km north of Gin Gin, and the stylo grazing trial about 25 km further north at 'Cedarvale' (151°40'E, 24°35'S). Both sites were on undulating country covered with black speargrass (*Heteropogon contortus*) into which the legumes had been oversown after a single cultivation. The cassia was sown in October 1984 and the stylo in December 1986. The legumes were well established at both sites and had been under constant grazing by steers at 2.4 ha/beast.

The trials were on duplex soils (Dy 3.41 and Dr 3.12), otherwise described as solodics or minor non-calcic browns (Northcote 1979) derived from granodiorite. Chemical analyses of adjacent soils, taken to the C horizon (Table 1), showed very low nitrogen, phosphorus and sulphur levels; these tended to decline with depth whereas pH increased.

Table 1. Chemical characteristics of soils adjacent to plots.

Depth	pH	N[1]	P[2]	K[3]	S[4]
(cm)			(mg/kg)		
Lundsville					
0–10	6.1	5	7	160	2
10–20	6.4	1	5	74	2
20–30	6.9	b/l[5]	3	74	4
30–40	7.3	b/l	3	70	b/l
Cedarvale					
0–10	6.1	b/l	5	94	4
10–20	6.4	b/l	2	47	3
25–40	7.0				
40–55	7.5				

Methods of analysis:
[1] Nitrate-N (1:5, soil:H_2O);
[2] Bicarbonate extractable P (Colwell);
[3] Extractable K (1:40, soil:0.05M HCl);
[4] Extractable SO_4-S (1:5, soil:0.1M Calcium phosphate).
[5] b/l = below method limit.

Treatments and design

Cassia. This trial was a factorial combination of 3 rates of phosphorus (0, 10, 40 kg/ha P as monocalcium orthophosphate Aerophos X®), 3 rates of sulphur (0, 10, 30 kg/ha S as gypsum), and two rates of molybdenum (0, 400 g/ha sodium molybdate). There were 4 replicates.

Stylo. The stylo trial was a factorial combination of 3 rates of phosphorus and 3 rates of sulphur, with 6 replicates. The rates and sources of nutrients, and plot size (4 m x 2 m) were similar to those in the cassia trial.

Establishment methods

The trial plots were superimposed on established grass/legume swards which had been grazed to a fairly uniform height of about 7 cm. The plots were fenced in September 1988 and all dried dung pats were removed.

Phosphorus and sulphur fertilisers were broadcast by hand over the relevant plots in September 1988 while sodium molybdate was applied as aqueous solution. No other basal nutrients were applied.

Measurements

Both trials were visually rated on March 18, 1989. The cassia trial was harvested on March 20, 1989 and the stylo trial on March 23, 1989. Legume tips (first 4 open leaves) were plucked for chemical analyses (N, P, K, S). A strip (1.4 x 3.2 m) was cut from each plot and weighed fresh; samples were taken for grass and legume separation and moisture analysis.

Results

Growing conditions

Growing conditions were good, with just under 700 mm of rain in the September to March period at each site.

Pasture response

In terms of vigour, yield and colour, there was a strong visual response to sulphur and a moderate response to phosphorus but no apparent response to molybdenum by cassia. The leaves of cassia without sulphur were pale green on a small plant, whereas those with sulphur were vigorous, lush and green. This effect was less visible on the stylo.

Yields of herbage

Cassia yield responded strongly to sulphur and showed a positive interaction with phosphorus — responding to phosphorus only when sulphur was applied (Table 2). The associated grass responded only to phosphorus at the highest rate when the yield increased from 2.91 to 3.41 t/ha; there was a second order interaction between sulphur, phosphorus and molybdenum.

Sulphur application increased the yield of shrubby stylo from 2.8 to 4.8 t/ha. Phosphorus had no effect on the yield of stylo or grass.

Mineral concentrations

Sulphur application increased nitrogen concentrations in cassia leaf tips at all phosphorus levels, but phosphorus had no effect without sulphur (Table 3). There were similar effects and interactions on the concentrations of sulphur, but phosphorus concentrations were increased by applying both phosphorus and sulphur. Potassium concentrations were increased only by sulphur (data not presented).

Sulphur application increased the concentrations of nitrogen, sulphur and potassium in stylo leaf tips, whereas applied phosphorus increased only the phosphorus concentration (Table 4).

The ratios of N:S decreased with increasing sulphur application; cassia declined from 21:1 without sulphur to 18:1 and 16:1 with 10 and 30 units of sulphur respectively; corresponding figures for stylo were 19:1, 16:1 and 15:1.

Table 2. Dry matter responses by cassia to sulphur and phosphorus fertilisers at Lundsville.

Fertiliser level (kg/ha)	S_0	S_{10}	S_{30}	Mean
		(t/ha)		
P_0	1.70	2.93	3.24	2.62
P_{10}	1.53	4.26	4.21	3.33
P_{40}	1.51	3.74	4.76	3.34
Mean	1.58	3.65	4.07	

LSD P,S (5%) = 0.508; (1%) = 0.679
LSD PxS (5%) = 0.883; (1%) = 1.176

Table 3. Effects of applied phosphorus and sulphur on concentrations of N, P and S in cassia leaf tips.

Level of applied nutrient (kg/ha)	S_0	S_{10}	S_{30}	Mean
		(N%)		
P_0	2.57	3.07	3.16	2.94
P_{10}	2.53	3.15	3.24	2.97
P_{40}	2.61	3.34	3.73	3.22
Mean	2.57	3.19	3.38	
LSD (5%) PxS = 0.199				
		(P%)		
P_0	0.21	0.21	0.21	0.21
P_{10}	0.23	0.26	0.26	0.25
P_{40}	0.25	0.32	0.35	0.30
Mean	0.23	0.26	0.28	
LSD (5%) PxS = 0.016				
		(S%)		
P_0	0.13	0.18	0.20	0.17
P_{10}	0.12	0.18	0.21	0.17
P_{40}	0.12	0.18	0.22	0.17
Mean	0.12	0.18	0.21	
LSD (5%) PxS = 0.013				

Table 4. Effect of applied sulphur and phosphorus on concentrations of N, P, S and K in stylo leaf tips.

Applied rate (kg/ha)	Mineral concentrations			
	N	P	S	K
		(%)		
S_0	2.22	0.21	0.12	1.80
S_{10}	2.45	0.20	0.15	1.91
S_{30}	2.49	0.21	0.17	2.10
P_0	2.37	0.19	0.14	1.91
P_{10}	2.36	0.20	0.15	1.98
P_{40}	2.44	0.23	0.15	1.92
LSD (5%)	0.095	0.011	0.008	0.087

Discussion

Legume responses

The sulphur response in pasture legumes from applying superphosphate was unexpected for this soil type; it had always been assumed that the responses obtained derived from the phosphorus component of the fertiliser. Sulphur deficiencies were not considered previously, being more typical on soils derived from basalt, in particular euchrozems in north Queensland (Miller and Jones 1977), and on deep sands (Andrew *et al.* 1974). However Probert and Jones (1982) showed responses by Caribbean stylo to sulphur, but unexpectedly not to phosphorus, on a neutral red duplex soil developed on granodiorite in north Queensland.

Deep-rooted forage legumes, once established, rarely show sulphur deficiencies despite low exchangeable sulphate in the soil surface horizons if the leached sulphur accumulates at depth (Probert 1974). However the deficiency can occur on low-sulphur soils that are near neutral throughout their profile because the sulphur is not adsorbed.

Sulphur is an important element in the synthesis of plant protein, there usually being a close relationship between nitrogen and sulphur concentrations in legume foliage. The response in nitrogen concentrations was much larger in cassia than in stylo, with cassia having a higher concentration, but lower yield, even when unfertilised. The nitrogen concentration in cassia leaf increased by 23% with sulphur and 45% with sulphur plus phosphorus whereas in stylo it increased by only 13%. The ratio of nitrogen to sulphur (N:S) can indicate critical levels of sulphur. Gilbert and Shaw (1989) suggest a critical ratio of 16:1 for Seca stylo, but higher ratios (up to 21:1) for faster-growing stylos. No critical values have been established for cassia, but as this trial indicated the lower rate of applied sulphur (10 kg/ha) provided sufficient of this nutrient, a sulphur concentration of 0.18% and an N:S ratio of 18:1 could be critical.

Although both legumes showed stronger responses to sulphur than to phosphorus, the differential responses between species cannot be compared between sites. Although chemical analyses of both soils showed low levels of phosphorus and sulphur, the Cedarvale site, with an original vegetation of blue gum (*Eucalyptus tereticornis*) and narrowleaf ironbark (*E. crebra*), has always been considered much better country than that at Lundsville (lemon-scented gum (*E. citriodora*) and narrowleaf ironbark).

Cassia did not respond to molybdenum, and the growth and colour of leaves and nodules in cassia receiving phosphorus and sulphur without molybdenum did not suggest any deficiency.

The associated grasses responded in yield only to phosphorus at Lundsville. As the mineral concentrations of the grass were not analysed, it is not clear whether the phosphorus effect was directly from the applied nutrient or indirectly from nitrogen fixed by the legume. The trials lasted only one growing season and there were no animals to aid circulation of nutrients through dung and urine. However herbage samples taken from the grazed cassia paddocks showed that grass associated with unfertilised cassia had 20% higher (40% when fertilised) nitrogen concentrations than unfertilised speargrass (Partridge and Wright 1992).

There were insufficient rates of fertiliser to clearly establish optimal responses, but around 10 kg/ha of sulphur appeared optimal for at least one season's growth. While there was no response to phosphorus at one site, there was at the other. To err on the safe side with these marginal-phosphorus soils, we have recommended the use of high-sulphur superphosphate (45% S, 7% P) rather than straight sulphur, especially for pastures that have received regular dressings of single super in previous years. Since fertiliser is usually applied every second year, at least 20 kg/ha of sulphur per application is recommended.

While sulphur could be supplied to grazing animals as a supplement, the inclusion of elemental sulphur in a phosphorus/salt lick at Cedarvale in the grazing trial had no effect (I.J. Partridge and J.W. Wright, unpublished data). Hunter *et al.* (1979) found supplemental sulphur reduced animal weight loss in winter but none of our steers lost weight because of adequate winter rainfall. In an area with reasonably reliable rainfall, applying sulphur to pasture gives the bonus of better quality (higher protein and more digestible) feed and of nitrogen cycling to the associated grass.

Implications

In recent years, the cost of superphosphate has been a major limitation to maximising pasture development in this relatively high rainfall region. Higher stocking rates are needed for an economic return from fertilising, but the desirable native pasture species may decline under such a practice.

If sulphur is more limiting than phosphorus, it can be supplied in high-sulphur analysis fertilisers, for example sulphur-fortified superphosphate, SF45® (7% P; 45% S). While 45% S-superphosphate may be 30% more expensive per tonne ex-factory than single superphosphate it contains four and a half times more sulphur and reduces transport charges per unit of sulphur.

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