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Effect of sulphur and phosphorus on two Stylosanthes species on a mottled grey earth in north-west Queensland

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Summary

The effect of sulphur and phosphorus on establishment, production and quality of *Stylosanthes humilis* and *S. hamata* was examined in two experiments on a low fertility, mottled grey earth soil of the Mayvale land system. In one experiment, light cultivation increased seedling density (81 m^{-2}) of *S. humilis* over burning (24 m^{-2}). Also, its yield was increased by 1.6 kg ha^{-1} S plus 19.2 kg ha^{-1} P on the cultivated seedbed (1140 kg ha^{-1}).

In the establishment year of the second experiment, rainfall (616 mm) was below average, and neither sulphur nor phosphorus had an effect on stylo seedling populations on a cultivated seedbed. *S. humilis* had a higher plant density (68 m^{-2}) than *S. hamata* (11 m^{-2}).

There was no yield response from either stylo to sulphur added alone, or with 19.2 kg ha^{-1} P, but adding the phosphorus increased yield of both species. This response was still present after 5 years. Nitrogen and phosphorus concentrations were not affected significantly by applying sulphur or phosphorus, although *S. humilis* had higher levels of these nutrients and of sulphur than *S. hamata*. The sulphur concentration of *S. humilis* in the presence of 19.2 kg ha^{-1} P was increased by adding 20 kg ha^{-1} S.

1. INTRODUCTION

The Mayvale land system in north-west Queensland comprises 16 000 km^2 of light textured infertile soils supporting low quality native pastures (Perry, Sleeman, Twidale, Prichard, Slatyer, Lazarides and Collins 1964). Webb, Beeston and Hall (1974) analysed profiles from nine soil types and found them to be low in nutrients.

Responses to sulphur and phosphorus by *Stylosanthes humilis* (Townsville stylo) have been measured in pot trials on nine soils from this land system (Webb 1975) and in a field experiment on one soil (Bishop 1974). Hall (1979a) has found *S. humilis* cultivars and *Stylosanthes hamata* cv. Verano to be among the most productive and persistent legumes evaluated for this area, and Hall (1979b) reported yield responses by both species to 300 kg ha^{-1} superphosphate.

Large properties use the pastures of the Mayvale land system for extensive grazing by cattle. One strategy for improving animal production is the development of *Stylosanthes* pastures based on low fertilizer inputs. Because of the remoteness of the region, freight costs account for much of the fertilizer costs. The use of high analysis fertilizers, such as double superphosphate (for example Super King), is a means of reducing freight costs per unit of phosphorus, but they contain low levels of sulphur.

The aim of these two experiments was to measure establishment, production and quality responses in *S. humilis* and *S. hamata* to adding various amounts of sulphur, with and without phosphorus, on a mottled grey earth soil of the Mayvale land system.

2. MATERIALS AND METHODS

Two experiments were established in a low open woodland of *Melaleuca viridiflora*, *Eucalyptus microtheca* and *Petalostigma banksii* with a ground cover of *Aristida* spp., *Sorghum plumosum* and *Chrysopogon fallax*. The site (141°9′E, 17°52′S), which was 24 km south east of Normanton, has been described in detail (No. 101) by Webb *et al.* (1974). The soil is a mottled grey earth, Gn 2.94 (Northcote 1971), with a hard setting surface. The soil profile (1 m) has low available P (3 to 10 ppm, sulphuric acid extraction), total N (0.03%), organic carbon (0.3%) and cation exchange capacity (1 to 4 meq per 100 g), a pH of 5.3 to 6.1, and a total sand content in the range 67 to 89%. Extractable sulphur (ppm) was 0.5 at 0 to 10 cm, 1.9 at 10 to 20 cm, 5.2 at 20 to 30 cm, 3.8 at 30 to 60 cm, 8.4 at 90 to 120 cm and 6.0 at 165 to 175 cm. The region has a hot monsoonal climate with 85% of rainfall occurring from December to March.

The design, establishment date, plot size and nutrient treatment details of the two experiments are shown in Table 1. In Experiment 2, the same S treatments were reapplied on 13 December 1973.

Table 1. Design, establishment date, plot size and treatment details of Experiments 1 and 2

Experiment	Design	Establishment date	Plot size	Treatment					
				Species*	Seedbed preparation	Nutrients (kg ha^{-1})			
							S	P	Mo
1	5 × 4 randomized block	20 Oct 71	3 × 5 m	*Stylosanthes humilis* (Greenvale strain)	No timber treatment: 1. Burn	1.	0	0	0
						2.†	0.8	9.6	0
						3.†	1.6	19.2	0
					2. Light cultivation	1.	0	0	0
						2.†	1.6	19.2	0
2	2 × 6 × 3 factorial	8 Dec 72	4 × 5 m	1. *Stylosanthes humilis* cv. Lawson 2. *Stylosanthes hamata* cv. Verano	Cleared timber: Complete cultivation (27 Sep and 28 Nov 72)	1.	0	0	0
						2.§	10	0	0
						3.§	20	0	0
						4.†	1.6	19.2	0
						5.#	20	19.2	0
						6.‡	20	19.2	0.04

*Planted at 12 kg ha^{-1} of uninoculated and untreated seed in pods.
†Super King.
‡Mo 12 Superphosphate.
§Sodium sulphate.
#Super King plus sodium sulphate.

Experiment 1. On 8 February 1972 and 14 March 1973, density of *S. humilis* and native species was determined in ten quadrats (0.125 m^2) per plot. Dry matter yields of sown legume, native grass and forbs (predominantly *Gomphrena flaccida*) were determined from clipping two quadrats (1 m^2) per plot on 4 May 1972. These samples were analysed for nitrogen and phosphorus concentrations. The site was grazed by cattle during the dry season of 1972 and at the end of the wet season in 1973.

Experiment 2. Establishment plant counts were recorded in ten quadrats (0.125 m^2) per plot on 13 March 1973. Dry matter yields of legume and other species were determined at the end of the first growing season (10 May 1973) by clipping two quadrats (0.5 m^2) per plot, and legume yields on 7 May 1975 and 3 May 1977 were determined by clipping two quadrats (1 m^2)

per plot. The dry matter yield of native species was low at all times following the pre-establishment cultivations. In 1975 and 1977, it was determined by clipping 10 random quadrats (1 m^2) across the experiment. All legume samples were milled and analysed for nitrogen and phosphorus, and those in 1973 were analysed for sulphur. In 1973 and 1977, native species samples were analysed for nitrogen and phosphorus. On 26 May 1977, five bulked soil samples (0 to 8 cm) were taken for chemical analyses from the nil nutrient, 1.6 kg ha^{-1} S + 19.2 kg ha^{-1} P and 20 kg ha^{-1} S + 19.2 kg ha^{-1} P + 0.04 kg ha^{-1} Mo treatments under both species.

Cattle were excluded from the experiment during the growing season, but were allowed access each dry season after sampling. In January 1974, the site was flooded in an abnormally wet summer. As a result, little plant growth occurred and the experiment was not sampled. In 1976, the experiment was accidently grazed and was not sampled because the P treatments, particularly the Lawson plots, were heavily grazed. The site was burnt by wild fires, which occur commonly in this region, in June 1973 and September 1976.

Rainfall

Monthly rainfall at Glenore Station, 2 km from the site, and long term means for Normanton are shown in Table 2. There were below average rainfall and a short growing season in the establishment year of experiment 2 and below average rainfall in March 1975.

Table 2. Rainfall (mm) recorded at Glenore Station for the duration of the experiment and long term mean at Normanton

Month	Rainfall at Glenore						Long term mean
	1971–72	1972–73	1973–74*	1974–75	1975–76	1976–77	104-year Normanton
Dec	122	38	231	169	215	177	145
Jan	214	151	965	245	483	126	265
Feb	326	394	289	236	360	216	255
Mar	381	33	359	58	78	212	158
Jul–Jun Total	1092	650	2104	741	1273	882	934

*Normanton records (Glenore recording station flooded).

3. RESULTS

Seedling establishment

In the first year of Experiment 1, there was no response in either sown legume or native species plant numbers to nutrient treatments, but light cultivation significantly ($P < 0.01$) increased legume seedling density (81 m^{-2}) over burning (24 m^{-2}). There was no difference in density of native species, both grasses and forbs combined (142 m^{-2}).

In the second year, there was a significantly higher legume density in the cultivation plus fertilizer treatment (63 m^{-2}) than in the other treatments (mean 7 m^{-2}).

In Experiment 2, establishment of both species was unaffected by nutrient treatments in the first season, but mean seedling densities were significantly greater ($P < 0.01$) for Lawson (68 m^{-2}) than for Verano (11 m^{-2}).

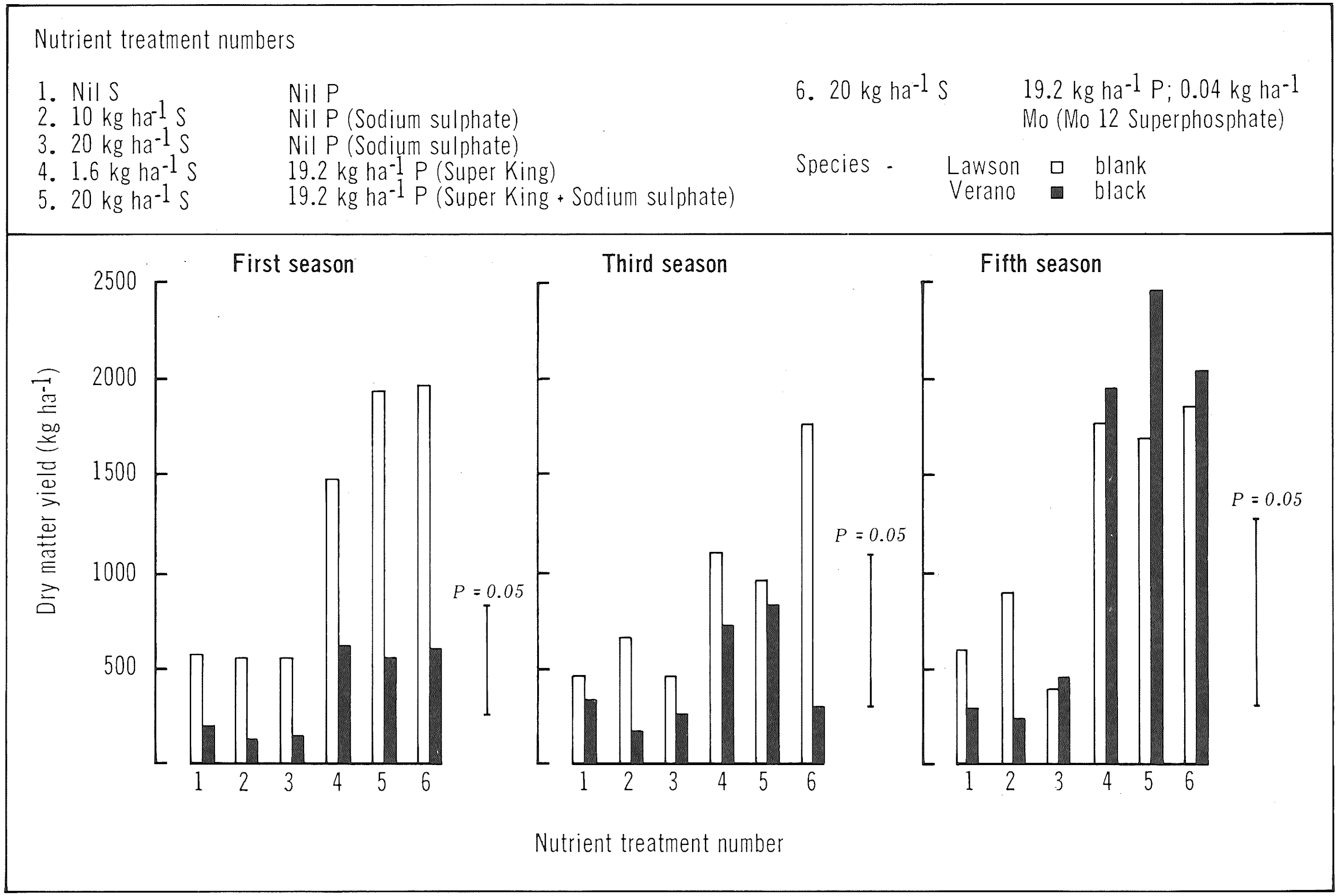

Figure 1. Dry matter yield (kg ha^{-1}) of Lawson and Verano in the first, third and fifth growing seasons.

Dry matter yield

In Experiment 1, there was a higher ($P < 0.01$) yield of legume in the cultivation plus fertilizer treatment (1140 kg ha^{-1}) than in all other treatments (mean 80 kg ha^{-1}). There were no differences in yield of native grasses (mean 900 kg ha^{-1}) between treatments. However *Aristida* spp. were dominant in burnt plots and *Schizachyrium fragile* in cultivated plots. The cultivated treatments had a higher yield of broad-leaved weeds, mainly *G. flaccida* (380 kg ha^{-1}) than the burnt treatments (90 kg ha^{-1}).

In the establishment year of Experiment 2 there was a large response by both legumes to P (mean yield of 1200 kg ha^{-1} in the presence of P compared with 350 kg ha^{-1} without P), but little evidence of a response to S (Figure 1). However, in P fertilized Lawson treatments, yield in plots receiving 20 kg ha^{-1} S were 40% (550 kg ha^{-1}) higher than in plots receiving 1.6 kg ha^{-1} S. This increase was almost significant at $P = 0.05$. The growth of Lawson was greater than that of Verano at all combinations of applied S plus P. Respective means were 1800 kg ha^{-1} and 600 kg ha^{-1}. The native species (predominantly annual grasses, *Aristida* spp. and *S. fragile*) had a higher yield ($P < 0.01$) in Verano (950 kg ha^{-1}) than in Lawson treatments (500 kg ha^{-1}).

At the end of the third growing season, the response to P was still evident and the mean legume yield of 1060 kg ha^{-1} with added P was more than double that in the nil P treatments. However, there was no evidence of a response to S. Lawson outyielded Verano (means were 860 and 520 kg ha^{-1}, respectively) and this superiority was particularly marked in the plus Mo treatment. The native grasses yielded 530 kg ha^{-1}.

By the fifth season, Verano was growing more vigorously and its yield was comparable to that of Lawson (mean 1200 kg ha^{-1}). The response to P applied 5 years previously remained, but there was again no response to S additions at either level of P. The native grass (*S. fragile, Aristida* spp. and re-established *S. plumosum* and *C. fallax*) yield showed no consistent response to nutrient treatments and varied from 400 to 1400 kg ha^{-1}.

Nitrogen, phosphorus and sulphur concentrations

Experiment 1. There were no significant differences in N concentration of *S. humilis* between treatments (mean 1.64%) in the first year. Nitrogen concentration of grasses was significantly higher in the *Aristida*-dominant burnt treatments (0.52%) than in the *S. fragile*-dominant cultivated treatments (0.39%).

The P concentration of legume was higher ($P < 0.01$) in the cultivated and fertilized plots (0.11%) than in all other treatments (mean 0.07%). In native grasses, the P concentration responded to P rate applied, irrespective of species: means were 0.03, 0.05 and 0.09% for the rates 0, 9.6 and 19.2 kg ha^{-1} P, respectively.

Experiment 2. The mean nutrient concentrations of Verano and Lawson are shown in Table 3. There were no significant differences in legume N concentration between nutrient treatments, but in the first season at the high P rate, Lawson had a significantly higher N concentration (2.06%) than Verano (1.46%).

The mean N concentration of both stylos declined over the 5 years, although values for Lawson were generally higher than for Verano. The mean N concentration of grasses remained low at 0.40% and 0.41% after the first and fifth growing seasons, respectively.

The application of S or P did not affect P concentrations in either stylo; however, the concentrations in Lawson were significantly higher than in Verano in the first and fifth growing seasons. The mean P concentration of grasses was 0.03% after the first and fifth growing seasons.

Table 3. Concentrations (%) of nitrogen, phosphorus and sulphur in tops of Lawson (L) and Verano (V) after the first (1), third (3) and fifth (5) growing seasons

Treatment			Nitrogen %						Phosphorus %						Sulphur %		N:S ratio	
Nutrients (kg ha^{-1})			1		3		5		1		3		5		1*		1	
S	P	Mo	L	V	L	V	L	V	L	V	L	V	L	V	L	V	L	V
0	0	0	1.89	1.68	1.84	1.40	1.81	1.44	0.07	0.07	0.06	0.04	0.07	0.05	0.15	0.12	13.1	13.8
10	0	0	2.14	2.11	1.60	1.93	1.64	1.67	0.08	0.08	0.05	0.06	0.07	0.07	0.14	0.13	14.8	16.8
20	0	0	1.95	1.64	1.85	1.61	1.80	1.38	0.07	0.06	0.06	0.05	0.06	0.05	0.15	0.11	12.7	14.5
1.6	19.2	0	1.83	1.73	1.54	1.80	1.63	1.20	0.07	0.07	0.05	0.06	0.07	0.05	0.13	0.11	14.5	15.4
20	19.2	0	1.94	1.41	1.73	1.26	1.54	1.23	0.08	0.06	0.06	0.04	0.06	0.04	0.15	0.11	13.0	13.3
20	19.2	0.04	2.18	1.51	1.55	1.71	1.50	1.16	0.09	0.06	0.05	0.06	0.06	0.05	0.16	0.10	13.9	15.2
Mean			1.99	1.68	1.68	1.62	1.65	1.35	0.08	0.07	0.05	0.05	0.07	0.05	0.15	0.11	13.7	14.8
s.e.			0.09		0.07		0.07		0.004		0.004		0.007		0.003		0.35	
l.s.d. (P = 0.05) (Means only)			0.18		n.s.		0.19		0.009		n.s.		0.01		0.01		1.04	

*Significant species × nutrient interaction l.s.d. (P = 0.05) = 0.021.

The addition of S alone did not affect S concentrations in either species; but in the presence of P, Lawson had a significantly higher S concentration in the 20 kg ha^{-1} S treatments (0.16%) than in the 1.6 kg ha^{-1} S treatment (0.13%). This response was not recorded in Verano, which generally had a lower S concentration than Lawson.

The N:S ratio of Verano was consistently higher than that of Lawson.

Soil chemical analyses

After five seasons there were no differences in chemical properties of soils between Lawson and Verano treatments. Phosphorus levels were <4 ppm, potassium was 0.05 meq per 100 g and organic carbon was 0.52% in the P treatments and 0.41% in the nil nutrient treatments.

4. DISCUSSION

On this hard setting surface, cultivation gave a higher legume density, but soil disturbance is not considered practical in this region; an initial density of 24 plants m^{-2} from planting in October following burning is sufficient for a new pasture. The lower density of Verano in the first year may be attributed to a high proportion of hard seed in the untreated seed (Mott and McKeon 1982). They found field germination was increased up to tenfold and pasture yield increased up to 15 times by heat treatment of Verano seed before sowing.

There was no firm evidence of a sulphur response, which is in contrast to pot trials on this soil (Webb 1975). This is not unusual. The weighted soil profile mean of 4.4 ppm S (Probert and Jones 1977) would suggest the soil S is just sufficient. A sub-optimal P supply, or alternatively deficiency of other nutrients such as Zn, may have limited legume growth. There was no response to Mo. On sandy soils with low total S levels (0.004%) on Cape York Peninsula, Jones (1973) found *S. humilis* yields responded to increasing S rates in the presence of 60 kg ha^{-1} P. At the low yield and S concentrations in legume in these experiments, there was a low demand for S.

The yield response to P supports pot studies on soils of this area (Webb 1975) and the field response by *S. humilis* found by Bishop (1974). The low yields of both legumes relative to those reported by Hall (1979b) for sandy soils of the same land system suggest also that nutrients, including P, were deficient. Bishop (1974) reported higher *S. humilis* yields from 48 to 192 kg ha^{-1} P than from 24 kg ha^{-1} P. However, the good residual effect of P, with responses still evident after 5 years even though soil P analysis shows little difference, is encouraging for practical stylo pasture development. Besides the low P rate, the low and poorly distributed rainfall in the establishment year of Experiment 2 could have contributed to the relatively low stylo yields.

Native grass yield in the fifth season varied between plots depending on the proportion of re-established perennial grass. There was no yield response in grasses to S and P in the legume plots. This is probably because of a severe deficiency of N, which limits production and persistence of introduced grasses on this soil (Hall 1979a).

At the end of the growing season tops of both stylos had relatively low N and P concentrations for legumes, and P was below the level (0.12%) considered necessary for growing cattle (Little 1980). Higher levels would be obtained in plant tips. The S concentration in Lawson was adequate for beef cattle in all treatments; but in Verano, S was at the minimum recommended (NRC 1976) concentration (0.10%). The N:S ratios were favourable at less than 17, which is supporting evidence for the lack of S response on this soil. Jones, Robinson, Haydock and Megarrity (1971) showed a steady decrease in the N:S ratio of *S. humilis* as the S supply increased on a S deficient soil.

On this mottled grey earth soil, double superphosphate, at low rates, is a suitable fertilizer for these two stylos. However, to exploit the higher yielding potential of Verano (Hall 1979b) and its greater resistance to anthracnose disease (*Colletotrichum gloeosporioides*) (Irwin and Cameron 1978), a study of a wider range of P and S rates on other sandy soils of the region is recommended.

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