NUTRIENT REQUIREMENTS OF *STYLOSANTHES HAMATA* CV. VERANO ON A EUCHROZEM NEAR CHARTERS TOWERS, NORTH QUEENSLAND

J. G. McIvor[1], M. E. Probert[2], C. J. Gardener[1] and F. W. N. Smith[3]

[1] CSIRO, Division of Tropical Crops and Pastures, Davies Laboratory, PMB, P.O. Aitkenvale, Qld. 4814.
[2] CSIRO, Division of Soils, Cunningham Laboratory, 306 Carmody Road, St Lucia, Qld. 4067.
[3] CSIRO, Division of Tropical Crops and Pastures, Cunningham Laboratory, 306 Carmody Road, St Lucia, Qld. 4067.

ABSTRACT

Pot and field experiments were conducted to determine the nutrient requirements of Stylosanthes hamata *growing on a euchrozem near Charters Towers in the semi-arid tropics of north-eastern Queensland. In pot experiments, significant responses were obtained to sulphur, phosphorus and copper; there was also a significant lime × sulphur interaction. However in the field, there was a significant response to sulphur only. The yield responses to sulphur applied in previous years suggest a considerable residual value for applied sulphur on this soil.*

Due to their adequate phosphorus status, high residual sulphur values, and absence of other nutrient deficiencies, the euchrozems offer better prospects for legume development than most of the soils in the region.

RESUMEN

Se condujeron experimentos en macetas y campo, para determinar los requerimientos nutricionales de Stylosanthes hamata *creciendo en un euchrozem cerca a Charters Towers en los trópicos semi-áridos de noreste de Queensland. Los experimentos en macetas, mostraron respuestas significativas para azufre, fósforo y cobre; hubo también una interacción significativa limo × azufre. Sin embargo en el campo, solamente hubo respuesta significativa al azufre. Las respuestas en producción a la aplicación de azufre en años anteriores, sugiere un efecto residual considerable del azufre en este suelo.*

Debido al estado adecuado de fósforo, alto niveles residuales de azufre y la ausencia de otras deficiencias de nutrientes, los suelos euchrozems ofrecen mejores perspectivas para el desarrollo de leguminosas, que la mayoria de los suelos en esta región.

INTRODUCTION

Red soils derived from basalt (euchrozems) (Isbell *et al.* 1976) occupy more than 16,000 km^2 in the semi-arid areas of north Queensland. Average annual rainfall in these areas varies from 400 to 900 mm, approximately 80% falling during December to March inclusive. The principal landscapes are broad, gently sloping plains supporting an open woodland dominated by *Eucalyptus crebra* and *E. dichromophloia.*

Current land use is extensive beef cattle grazing on native pastures (*Themeda triandra, Heteropogon contortus* and *Bothriochloa ewartiana*). Beef production is limited by the low quality and/or quantity of the native herbage available during the dry season but there are good prospects for introducing legumes into the pasture to overcome this limitation. Suitable legume cultivars such as *Stylosanthes hamata* cv. Verano and *S. scabra* cv. Seca are available that can be cheaply established by oversowing the open woodland communities. However, before pasture improvement can be successfully undertaken it is necessary to know the fertilizer requirements of pasture species on particular soils. The euchrozems have high levels of available phosphorus (Isbell *et al.* 1976) but low levels of extractable sulphur (Probert 1977). On a euchrozem near Mt Garnet (average annual rainfall, 760 mm), Miller and Jones (1977) found *S. guianensis* responded strongly to sulphur but not to other elements. At a nearby site, on a similar soil, Gilbert and Shaw (1981) confirmed the sulphur response, and cattle grazing unfertilized *S. guianensis* pasture during the dry season gave a positive liveweight response to sulphur (and sodium) supplement (Hunter *et al.* 1979).

There are no comparative studies of sulphur responses of *Stylosanthes* species. Species other than *S. guianensis* (e.g. *S. hamata*, Probert and Jones 1982) respond to sulphur application but it is not known if responses are of a similar magnitude to those of *S. guianensis*. Also, responses may be different on euchrozems in drier areas to those near Mt Garnet. To provide information on these aspects we have assessed the need for added nutrients in pot trials and then established the importance of any likely deficiencies in field trials at Hillgrove near Charters Towers.

MATERIALS AND METHODS

Experimental site

Soil for pot experiments was collected from, and field trials were located at, 'Hillgrove', 80 km north-west of Charters Towers. The soil, a euchrozem developed on basalt of the Nulla Province (Twidale 1956), is similar to those described by Isbell *et al.* (1976). The surface soil (0–10 cm) has the following properties (determined by the methods of Isbell *et al.* (1976) and Probert and Jones (1977)).

pH (1:5 soil:water suspension)	6.1	
extractable phosphorus –0.01 N H_2SO_4	57	ppm
extractable phosphorus –0.5 M $NaHCO_3$	54	ppm
extractable sulphur –0.01 M $Ca(H_2PO_4)_2$	1.3	ppm
organic carbon	1.25	%
exchangeable calcium	14.8	me%
exchangeable magnesium	3.8	me%
exchangeable potassium	1.6	me%
exchangeable sodium	0.03	me%

Extractable sulphur is less than 2 ppm in the upper 60 cm of the profile but increases slightly to 4 ppm in the 80–100 cm layer.

Average annual rainfall at Hillgrove is 535 mm with 76% falling during December–March inclusive. Frosts occur in most years. Annual evaporation is 1900 mm. The median length of the growing season (determined by the method of McCown 1973) is 14 weeks.

Pot experiments

Three pot experiments were conducted using surface soil (0–10 cm). Experiment 1 was a half-factorial ($\frac{1}{2} \times 2^7$) where the factors were phosphorus, potassium, sulphur, molybdenum, calcium, zinc and a mixture containing copper, magnesium, boron and manganese. For each nutrient the treatment levels were nil, and the rate shown in Table 1.

TABLE 1

Nutrient treatments in Experiment 1 and 2

Nutrient	Rate (kg/ha)	Compound
P	40	$Ca(H_2PO_4)_2.H_2O$
K	50	$KHCO_3$
S	30	Na_2SO_4
Mo	0.5	$(NH_4)_6Mo_7O_{24}.4H_2O$
Lime	1000	$CaCO_3$
Zn	20	$ZnCl_2$
Mixture		
Cu	10	$CuCl_2.2H_2O$
Mg	50	$MgCl_2.6H_2O$
B	5	H_3BO_3
Mn	10	$MnCl_2.4H_2O$

In Experiment 2, responses to the individual nutrients in the micro-element mixture of Experiment 1 were measured. The trial consisted of 2 replicates of a 2^4 factorial where the factors were magnesium, copper, manganese and boron at the same rates as those used in the first trial. A basal application of phosphorus, sulphur, potassium, molybdenum and zinc was applied.

The effect of rate of phosphorus application was examined in Experiment 3. Phosphorus (as $Ca(H_2PO_4)_2.H_2O$) was applied at rates equivalent to 0, 25, 50, 100, 150 and 200 kg/ha together with a basal application of potassium, sulphur, molybdenum and zinc. There were 3 replicates.

Pots contained 1800 g of air dry soil. They were sown on October 5, 1981 with *S. hamata* cv. Verano inoculated with Rhizobium strain CB82 and thinned to 6 plants per pot on October 19. The pots were watered to field capacity daily with demineralized water and kept in a glasshouse at the Cunningham Laboratory, Brisbane. The plants were harvested on December 21 by cutting at the cotyledon scar level and oven drying the tops. All plant roots were well nodulated.

Field trials

After considering the results of the pot experiments, 2 field trials were conducted: a phosphorus × sulphur factorial trial and a multi-nutrient trial. The native grass on the trial area was burnt and trees within 10 m of the plots killed by injection with arboricide. The plots (each 4 × 3 m) were fertilized and oversown to *S. hamata* cv. Verano on January 12, 1983.

Phosphorus × sulphur factorial

The initial treatments were 6 phosphorus rates (0, 5, 10, 20, 40 and 100 kg/ha as $Ca(H_2PO_4)_2.H_2O$) and 5 sulphur rates (0, 5, 10, 20 and 40 kg/ha as $CaSO_4.\frac{1}{2}H_2O$) with 2 replicates.

Subsequently, the effects of a fresh application of sulphur were examined. Additional sulphur (20 kg/ha as $CaSO_4.\frac{1}{2}H_2O$) was applied on October 30, 1984 to one sixth of the plots receiving each of the initial sulphur treatments. The plots to receive additional sulphur were selected at random irrespective of the initial phosphorus treatments.

Multi-nutrient trial

This trial was a half replicate of a 2^6 factorial where the factors were the presence or absence of potassium (50 kg/ha), magnesium (10 kg/ha), copper (3 kg/ha), zinc (3 kg/ha), molybdenum (0.2 kg/ha) and boron (0.3 kg/ha). A basal dressing of 40 kg/ha of both phosphorus and sulphur was applied.

Harvesting/sampling details

Samples of Verano (plant tips of 3–4 leaves plus unexpanded leaves and inflorescences) were taken on June 18, 1983 and March 19, 1984 for chemical analysis (Johnson *et al.* 1985). Dry matter yields were measured on March 28, 1984 and March 13, 1986 by cutting two 1 × 0.5 m quadrats to ground level from each plot and determining oven dry weight. Botanical composition was estimated from visual observations by 5 observers using a calibration established between the visual estimate and the actual proportion of Verano found after hand-sorting the harvested material from a selection of the plots. At the end of each dry season standing material was mown to 10 cm and the herbage removed from the plots.

RESULTS

Pot experiments

Significant responses were obtained to phosphorus and sulphur with a smaller response to lime (Table 2); the lime × sulphur interaction also reached significance (P

< 0.05, data not presented). In addition there was a response to copper in experiment 2. The response to phosphorus was almost linear with yields increasing by 33% at the highest application rate.

TABLE 2

Plant yield responses to applied nutrients in pot experiments

Experiment	Nutrient	Herbage Yield		Significance of response[1]
		Without nutrient	With nutrient	
		(g/pot)		
	P	4.47	5.24	***
1	S	3.96	5.75	***
	Lime	4.75	4.97	*
2	Cu	6.21	6.98	**

[1] *** $P < 0.001$; ** $P < 0.01$; * $P < 0.05$

Field trials

Growing conditions

Rainfall was below average during January–March 1983 (128 mm compared with 338 mm) and establishment and growth of the Verano plants was poor. Total pasture yields in July 1983 were estimated to be less than 1000 kg/ha with Verano comprising less than 5% of the herbage.

Rainfall was much higher during the 1983–84 growing season (547 mm during November–March) with correspondingly good growing conditions. Conditions were again poor in 1985 and no harvests were made. During 1985–86, growing conditions were similar to those in 1983–84 (550 mm between October and March).

Multi-nutrient trial

Treatments had no significant effect on yields of Verano or native grass. Verano shoots sampled in March 1984 contained 3.0% N, 0.15% P, 0.19% S, 1.9% K, 1.5% Ca, 0.26% Mg, 11 ppm Cu, 46 ppm Zn, 68 ppm Mn and 19 ppm B (means of all treatments).

Phosphorus × sulphur factorial

Phosphorus treatment had no effect on the yield of Verano or on the chemical composition of Verano shoots; the plants grown without phosphorus contained 0.17% P in the June 1983 samples and 0.14% in March 1984.

Verano responded to sulphur application (Table 3). In 1984 the response was significant with no well-defined maximum yield. When the linear and quadratic components of the analysis of variance were considered, only the linear effect was significant. In 1986, plots which received an initial application of 40 kg/ha and those where 20 kg/ha had been applied prior to the 1985 season produced greater herbage yields than plots which initially received 20 kg/ha or less.

TABLE 3

Pasture responses to sulphur application at Hillgrove

Application rate of S	Yield of *S. hamata*	
	1984	1986
	(kg/ha)	
0	1830	1660
5	1520	1730
10	2020	1640
20	1920	1710
40	2430	3450
20[1]	—	3330
LSD ($P = 0.05$)	560	1550

[1] Additional S applied prior to the 1985 growing season.

Sulphur application also increased nitrogen and sulphur concentrations in Verano shoots sampled in 1983 and 1984, and decreased N:S ratios (Fig. 1).

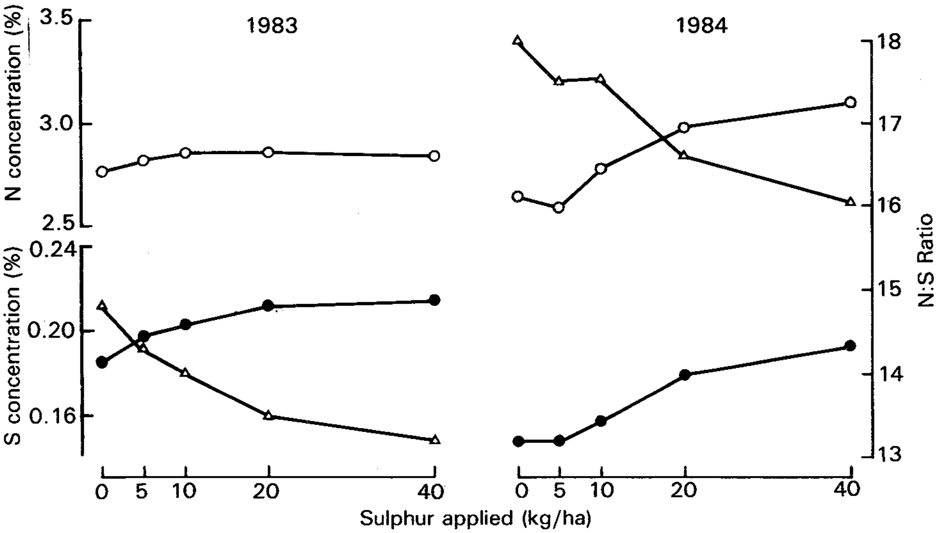

FIGURE 1

Effects of sulphur application on the nitrogen (o) and sulphur (●) concentrations and N:S ratios (Δ) in Verano shoots

DISCUSSION

These experiments demonstrated that sulphur was the only deficiency for legume growth on the euchrozem at Hillgrove. Although there were responses to other nutrients (phosphorus, copper, lime) under the favourable glasshouse conditions, no responses were obtained in the field and the chemical analyses suggest other deficiencies are unlikely to occur. The absence of a response to phosphorus on the euchrozems (Miller and Jones 1977; this study) contrasts with phosphorus deficiency on most other soils in north Queensland (e.g. Jones and Crack 1970; Kerridge *et al.* 1972; Teitzel and Bruce 1972; Jones 1973; Webb 1975; Probert and Williams 1985; Gilbert and Shaw 1987; Gilbert *et al.* 1987). Only the neutral red duplex soil investigated by Probert and Jones (1982) showed similar responses to the euchrozems. The amounts of extractable phosphorus in euchrozems are high compared with other soils in the region (Isbell *et al.* 1976) but extractable phosphorus may not be the most appropriate means of evaluating the ability of a soil to supply phosphorus to plants because of differences in sorption characteristics between soils. Probert and Jones (1982) discussed the absence of a phosphorus response in terms of the external phosphorus requirement derived from phosphorus sorption data and suggested the critical value to be below 0.015 μg P/ml for Verano. The external phosphorus concentration in the surface 0–10 cm at Hillgrove was 0.021 μg P/ml so on this basis, the absence of a response could be predicted. The small, but significant, response to high (150–200 kg P/ha) rates of phosphorus in the pot trial was probably due to the plants being more responsive under the good growing conditions, and to the lower variability between replicates giving a small, and thus significant, LSD.

Poor growing conditions prevented yield data being obtained in 1983 and 1985. However the sulphur treatments applied prior to the 1983 season were clearly still effective in 1984, whilst the initial sulphur application of 40 kg/ha and the application of 20 kg/ha prior to the 1985 season were still effective in 1986. This suggests the residual value for applied sulphur will be higher at Hillgrove than on the euchrozems near Mt Garnet where low sulphur application rates (10–20 kg/ha) had very limited residual value (Gilbert and Shaw 1981) although high rates (50–100 kg/ha) had stronger effects (Miller and Jones 1977; Gilbert and Shaw 1981). The differences between Hillgrove and the Mt Garnet area can be attributed to the recovery and removal of applied sulphur in the herbage, and to leaching. Gilbert and Shaw (1981) reported a relatively high (40–60%) recovery over 2 years from sulphur applied at 5–50 kg/ha and most of this was in the year of application. In our experiment, sulphur uptake at similar application rates was much lower (10%), predominantly because pasture yields were smaller. Although we did not make any measurements of leaching, losses of sulphur from the rooting zone under the lower rainfall at Hillgrove would probably have been less than Gilbert and Shaw (1981) found at Mt Garnet. Their data show that in 1 year sulphur did move down the profile, whilst in other years there was no evidence that residual sulphur remained in the top 30 cm of soil. In contrast, on a neutral red duplex soil near Charters Towers, Probert and Jones (1982) found that most of the applied sulphur not taken up by the pasture remained in the profile and good residual effects were obtained. It appears the situation at Hillgrove was more akin to that reported by Probert and Jones (1982) than to the wetter Mt Garnet area (Gilbert and Shaw 1981).

Miller and Jones (1977) suggested that N:S ratio in herbage of *S. guianensis* was a reasonable indicator of sulphur deficiency. The significant response in Verano yields in 1984 was accompanied by N:S ratio in deficient plants of greater than 17. However it would seem that the poor, first season growth of Verano was not affected by sulphur deficiency. The plants had a N:S ratio less than 15, and the application of sulphur had only small effects on nitrogen concentration in the plants. The sulphur response could be predicted from the low (less than 4 ppm) level of phosphate-extractable sulphur in the soil (Probert and Jones 1977).

Low and variable rainfall and rocks on or near the soil surface preclude cropping on most euchrozems and they will continue to be utilized for beef production in the forseeable future. Since they have adequate phosphorus status, sulphur applications appear to have high residual values, and other nutrient deficiencies are absent, the euchrozems offer better prospects for legume development than most other soils. Whilst the actual levels of sulphur application needed must be determined under grazing, the strong residual effects and the small sulphur removal by cattle suggest that only small and/or infrequent applications will be needed. In many situations, the application of superphosphate provides sufficient sulphur as well as phosphorus to overcome deficiencies. However in situations such as the euchrozems where phosphorus is not deficient, gypsum is a suitable sulphur fertilizer (Gilbert and Shaw 1981). Gypsum is available in the Burdekin Irrigation Area and, depending on freight and application costs, may provide a cheaper source of sulphur.

ACKNOWLEDGEMENTS

We thank Mr T. H. Mann for the use of his land and Messrs W. M. Pieters, P. E. J. Allen, W. A. Beyer, L. V. Whiteman and I. Salins for technical assistance.

REFERENCES

GILBERT, M. A., MOODY, P. W. and SHAW, K. A. (1987)—Fertility assessment of soils of the Mt Garnet area, north Queensland. *Australian Journal of Experimental Agriculture* **27**: 93–100.

GILBERT, M. A. and SHAW, K. A. (1981)—Residual effects of sulphur fertilizers on cut swards of a *Stylosanthes guianensis* and native grass pasture on a euchrozem soil in north Queensland. *Australian Journal of Experimental Agriculture and Animal Husbandry* **21**: 334–342.

GILBERT, M. A. and SHAW, K. A. (1987)—Fertility of a red earth soil of Mid-Cape York Peninsula. *Australian Journal of Experimental Agriculture* **27**: 863–868.

HUNTER, R. A., SIEBERT, B. D. and WEBB, C. D. (1979)—The positive response of cattle to sulphur and sodium supplementation while grazing *Stylosanthes guianensis* pastures in north Queensland.

Australian Journal of Experimental Agriculture and Animal Husbandry **19:** 517–521.

Isbell, R. F., Stephenson, P. J., Murtha, G. G. and Gillman, G. P. (1976)—Red basaltic soils in north Queensland. CSIRO Australia Division of Soils Technical Paper No. 28.

Johnson, A. D., Simons, J. G., Hansen, R. W. and Daniel, R. A. (1985)—Chemical procedures for the analysis of plant material: multielement, oil, sugars and gum. CSIRO Australia Division of Tropical Crops and Pastures Tropical Agronomy Technical Memorandum No. 40.

Jones, R. K. (1973)—Studies on some deep sandy soils in Cape York Peninsula, north Queensland. 2. Plant nutrient status. *Australian Journal of Experimental Agriculture and Animal Husbandry* **13:** 89–97.

Jones, R. K. and Crack, B. J. (1970)—Studies on some solodic soils in north-eastern Queensland. 2. Glasshouse assessment of plant nutrient status. *Australian Journal of Experimental Agriculture and Animal Husbandry* **10:** 342–349.

Kerridge, P. C., Andrew, C. S. and Murtha, G. G. (1971)—Plant nutrient status of the soils of the Atherton Tableland, north Queensland. *Australian Journal of Experimental Agriculture and Animal Husbandry* **12:** 618–627.

McCown, R. L. (1973)—An evaluation of the influence of available soil water storage capacity on growing season length and yield of tropical pastures using simple water balance models. *Agricultural Meteorology* **11:** 53–63.

Miller, C. P. and Jones, R. K. (1977)—Nutrient requirements of *Stylosanthes guianensis* pastures on a euchrozem in north Queensland. *Australian Journal of Experimental Agriculture and Animal Husbandry* **17:** 607–613.

Probert, M. E. (1977)—The distribution of sulphur and carbon-nitrogen-sulphur relationships in some north Queensland soils. CSIRO Australia Division of Soils Technical Paper No. 31.

Probert, M. E. and Jones, R. K. (1977)—The use of soil analysis for predicting the response to sulphur of pasture legumes in the Australian tropics. *Australian Journal of Soil Research* **15:** 137–146.

Probert, M. E. and Jones, R. K. (1982)—Studies on some neutral red duplex soils (Dr 2.12) in north-eastern Queensland. 4. Field studies of nutrient responses with Caribbean stylo. *Australian Journal of Experimental Agriculture and Animal Husbandry* **22:** 382–390.

Probert, M. E. and Williams, J. (1985)—The residual effectiveness of phosphorus for *Stylosanthes* pastures on red and yellow earths in the semi-arid tropics. *Australian Journal of Soil Research* **23:** 211–222.

Teitzel, J. K. and Bruce, R. C. (1972)—Fertility studies of pasture soils in the wet tropical coast of Queensland. 3. Basaltic soils. *Australian Journal of Experimental Agriculture and Animal Husbandry* **12:** 49–54.

Twidale, C. R. (1956)—A physiographic reconnaissance of some volcanic provinces in north Queensland, Australia. *Bulletin of Vulcanology* **18:** 2–23.

Webb, A. A. (1975)—Studies on major soils of the Forsayth Granite. 2. Glasshouse nutrient assessment. *Queensland Journal of Agricultural and Animal Sciences* **32:** 37–45.

(Submitted for publication, January 10, 1988; accepted May 13, 1988)