Response of *Stylosanthes hamata* cv. Verano and native pastures to fertilisers on two light-textured soils in north-west Queensland

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Abstract

The effects on yield and quality of applying fertilisers to *Stylosanthes hamata* cv. Verano (Caribbean stylo) and to native pastures were measured in 3 field experiments on a grey kandosol and a brown sodosol supporting *Melaleuca* woodlands in north-west Queensland.

Phosphorus application at a rate of 30 kg/ha P increased Verano yield annually in the first 4 years. The maximum yield achieved was >6000 kg/ha on a grey kandosol in the second year. Eighty percent of maximum legume yield was achieved with acid-extractable soil P levels of 8 mg/kg. There was also a yield response to sulfur and zinc at establishment, but not in subsequent years. The nutrient concentration responses of Verano to fertilisers are reported. Dry matter yield of native pasture was increased by both nitrogen (from 2050–3630 kg/ha) and superphosphate (to 3080 kg/ha) fertiliser in the first year, but not in the second growing season when rainfall was low. Concentrations of P and S in the native pasture were increased by superphosphate (from 0.03% and 0.07% to 0.12% and 0.10% respectively) in the first season.

Productive Verano pastures with nutrient concentrations adequate for animal production can be grown on these infertile soils by applying single superphosphate alone. Most commercial pastures are not adequately fertilised and an application of 30 kg/ha P every 5 years is suggested.

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Introduction

The forest country of the south-east Gulf of Carpentaria extends over 4 degrees of latitude (Isbell *et al.* 1968) with light-textured soils of low P status (Webb *et al.* 1974). Cattle graze these pastures at low stocking rates, but still have poor growth and reproductive rates. Sown legume pastures increase beef production by improving feed quality. *Stylosanthes hamata* cv. Verano (Caribbean stylo) is widely-sown in the dry tropics and grows poorly on these soils without fertilisation (Hall 1979). Verano responds to P fertiliser (Hall 1982), but optimum levels of P and responses to other nutrients in the field have not been clearly defined. In glasshouse studies on these soils, Townsville stylo (*Stylosanthes humilis*) exhibited marked responses to P and S (Webb 1975).

The commercial practice of applying 10 kg/ha P at irregular intervals to Verano pastures, as either single (9.6% P, 10% S) or triple (19.2% P, 1.6% S) superphosphate is based on financial constraints and not on pasture performance data. Consequently, these pastures are often growing below potential. The effects of N and P fertilisers on native pastures are also unknown. To determine the fertiliser requirements of Verano, a nutrient omission experiment and an experiment incorporating various rates of P and S were established on 2 light-textured soils of the Mayvale land system (Perry *et al.* 1964). To determine the effects of improved soil fertility on native pasture, a third experiment recorded the response of the native species, predominantly grasses, to N and P fertiliser.

Materials and methods

Sites

In December 1973, 2 Verano experiments were established on a basic, subnatric, brown sodosol (Isbell 1993) (a duplex soil, Dy 3.82, Northcote 1971) of the Gum Creek association (Webb *et al.* 1974) at Timora Station (141° 29′E, 17° 54′S), near Normanton. In December 1974, duplicate Verano experiments were established on a bleached-ferric, mesotrophic, grey kandosol (Isbell 1993) (a gradational soil, Gn 2.94), of the Blackbull association at Mayvale Station (141° 47′E, 17° 58′S). The native pasture experiment on the grey kandosol commenced in December 1978. Both soils are kandiustalfs according to soil taxonomy (Soil Survey Staff 1990). The sites were located in low, open *Melaleuca* woodland on flat plains of the Mayvale land system.

The soils had similar chemical properties, except for extractable S and K levels. The extractable S levels remained below 4 mg/kg down the grey kandosol profile, but increased to 13 mg/kg at 80 cm in the brown sodosol, which also had a texture contrast at 30 cm (Table 1).

The tree vegetation was *Melaleuca viridiflora* and *Petalostigma banksii* with occasional *Eucalyptus polycarpa* and *Erythrophleum chlorostachys* emergents. *Chrysopogon fallax* (dominant on the grey kandosol), *Aristida* spp. (dominant on the brown sodosol), *Schizachyrium fragile* and *Sorghum plumosum* were the main grasses.

Average annual rainfall at both sites is 820 mm with 85% falling from December–March inclusive. Annual pan evaporation is 3100 mm. Mean maximum temperature in November is 38 °C and mean minimum in July is 14 °C. Frosts do not occur.

Treatments and design

The Verano experiments were randomised block designs with 4 replications, and the native pasture experiment was a factorial design with 3 replications arranged in blocks. Plot size for all experiments was 5 x 5 m, and seed and nutrients were hand broadcast after mixing with fine, dry sand.

Experiment 1: Verano omission trial was a nutrient omission design with the following 10 treatments: A control treatment received P, S, K, Zn, Cu, Mo, Fe, and Co; 5 treatments received the control treatment less either S, K, Zn, Cu or Mo; a further 3 treatments received the control nutrients plus either Mg, (Mn + B) or lime; and one treatment received no fertiliser. The nutrients, forms and rates of compound (kg/ha) were: S-Na_2SO_4 (133.3); Mn-$MnCl_2.4H_2O$ (10.0); K-KCl (125.0); B-$Na_2B_4O_7.10H_2O$ (5.0); Zn-$ZnSO_4.7H_2O$ (11.0); Ca-$CaCO_3$ (500.0); Cu-$CuCl_2.2H_2O$ (6.0); P-$CaH_4(PO_4)_2.H_2O$ (243.9); Mo-$(NH_4)6Mo_7O_{24}.4H_2O$ (0.57); Fe-$[CH_2.N(CH_2.COO)_2]_2.FeNa$ (5.0); Mg-$MgCO_3$ (250.0); Co-$CoCl_2.6H_2O$ (0.3).

Experiment 2: Verano fertiliser rates trial consisted of 15 treatments of various P and S combinations. There were 5 P rates (10, 20, 30, 60, 100 kg/ha) and 2 fertiliser sources (commercial single and triple superphosphate); an additional 3 treatments received 60 kg/ha P as triple superphosphate plus either 10, 20 or 40 kg/ha S applied as Na_2SO_4; basal nutrients (K, Zn, Cu, Mo, Mn, B, Ca, Co, Mg and Fe) were applied at the rates used in experiment 1, to all these P and S treatments; one treatment with the basal nutrients only; and a nil nutrient treatment. Two replications at both sites received an additional 20 kg/ha P as single superphosphate in December 1978.

Experiment 3: Native pasture fertiliser trial had 3 N rates (0, 25, 75 kg/ha) as Nitram and 4 P rates (0, 10, 30, 60 kg/ha) as single superphosphate.

Planting and soil preparation

The native pasture used for Verano studies was burnt prior to applying treatments and scattered unburnt tussocks on the grey kandosol were spot sprayed with paraquat. The brown sodosol was also cultivated with a rotary hoe. Trees were undisturbed. Uninoculated, podded Verano seed was sown at a rate of 10 kg/ha on to a dry soil surface. The native pasture experiment site was burnt in November 1977 and grazed heavily prior to applying treatments.

Grazing

Cattle grazed the experimental areas each year during the dry season (May–November), and just prior to the start of the wet season remaining material was mown to 5 cm and removed.

Table 1. Chemical and physical properties[1] of the grey kandosol (GK) and brown sodosol (BS) profiles.

Depth	pH 1:5 water		P acid extr.		K repl.		N-(NO_3) extr.		S extr.		Cl^- extr.		Zn extr.		Sand		Silt		Clay	
	GK	BS	GK	BS	GK	BS	GK	BS	GK	BS	GK	BS	GK	BS	GK	BS	GK	BS	GK	BS
(cm)			(mg/kg)		(mg/kg)		(mg/kg)		(mg/kg)		(mg/kg)		(mg/kg)		(%)		(%)		(%)	
0–10	6.2	5.7	2	3	0.08	0.05	5	2	0.9	0.8	7	8	0.2	0.2	88	89	4	3	8	8
10–20	5.9	6.0	1	1	0.08	0.33	4		1.1	1.1					88	90	4	2	8	8
20–30	5.8	6.0	1	1	0.08	0.20	3		1.2	0.9					80	87	4	2	16	11
30–40	5.9	6.0	1	1	0.08	0.20	4		0.7	0.5					82	61	4	1	30	38
40–60	5.9	6.6	1	1	0.07	0.20	3	1	3.7	2.5	9	10			68	61	2	1	30	38
60–80	6.2	6.5	1	1	0.05	0.05	3		3.2	7.7					67	63	3	2	30	37
80–100	6.4	6.9	1	1	0.04	0.05	3	2	2.8	13.4	8	19								
160–200									0.9	3.5										

[1] Methods are described by Rayment and Higginson (1992).

Sampling and analyses

At the sodosol site, Verano seedling populations were recorded in four 0.5 m^2 quadrats per plot in May 1974 and 1977. At both sites, dry matter yields of Verano and native grass were recorded in April–May when Verano was flowering and seeding. Yields were measured from 1974–1979 by cutting to 5 cm in two 0.5 m^2 or 1 m^2 quadrats per plot. In the native pasture experiment, botanical composition and yield (three 0.5 m^2 quadrats per plot) were measured in May 1978 and 1979. All samples were held for nutrient analyses. Analyses of variance were used to test differences in Verano dry matter yield between the 2 P forms and the 6 rates. The means of 16 quadrats were plotted for P rate (forms combined) and equations of the form $y = a + b\exp^{cx}$ were fitted. Adjusted r^2 values describe the goodness of fit.

The N and P concentrations of Verano tops were determined before flowering in 1975, and the harvested samples (whole tops) from each replication were analysed each year. The yield samples were then bulked across the 4 replications of each experiment and analysed for K, S, Zn, Ca, Mg, Cu and Mn. Samples from the native pasture experiment (whole tops) were analysed for N, P, S, K, Ca, Mg and Na.

Soil samples (0–10 cm) from experiment 2 at both sites were analysed for P (0.005 M H_2SO_4 acid-extractable) in August 1976 and December 1978. Three unfertilised profiles to 2 m at both sites were analysed for phosphate-extractable S (Barrow 1967). Relative Verano yields (percentage of maximum yield at each harvest) on both soils in 1976 and on the kandosol in 1978, were plotted against soil acid-extractable phosphorus level. A Mitscherlich curve was fitted to the 3 data sets combined.

Results

Rainfall at Gum Creek Station, 10 km from both sites, varied from flood conditions, >1500 mm (1973–74) to drought, 329 mm (1977–78), compared with the long-term average of 700 mm for the main growing period. The length of the growing period varied from <2 months (1978) to almost 6 months (1977) (Table 2).

Verano response to fertilisers

Omission experiment (1)

Verano established and regenerated well in all experiments every year (>100 seedlings/m^2 in all treatments in 1977), except in the abnormally wet summer of 1973/74 when fewer than 8 mature plants/m^2 established on the sodosol. Indigenous rhizobia effectively inoculated Verano. However, seedlings in the nil, –Zn and –S treatments were a paler green than those in other treatments for the first 2 years.

Dry matter yield. In the establishment year on the grey kandosol, Verano yield was significantly ($P<0.05$) lower when grown without Zn (1550 kg/ha) and without S (2490 kg/ha) compared with the control nutrient treatment (2880 kg/ha). In succeeding years there were no significant ($P>0.05$) yield responses without Zn or

Table 2. Monthly rainfall (mm) at Gum Creek Station, 10 km from the experiments and long-term mean rainfall (103 years) for Normanton.

Year	Wet season month						Season	Annual
	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	Nov.-Apr.	Jul.-Jun.
1973–74[1]	NR[2]	200+	909+	200+	177+	NR	>1500	>1500
1974–75	11	109	195	167	90	4	576	610
1975–76	12	192	271	295	91	10	871	968
1976–77	105	184	53	237	116	40	735	764
1977–78	36	115	113	57	4	2	327	329
1978–79	38	93	311	466	299	36	1243	1274
1979–80	27	84	237	195	35	30	608	634
1980–81	12	55	534	293	7	2	903	962
Normanton	44	145	265	255	151	31	891	934

[1] Records incomplete — flooding.
[2] Not recorded.

S, although the minus S treatment consistently had 76% lower yield than the control. In all years, Verano yield was significantly higher in the fertilised (all include P) treatments (mean 3340 kg/ha, range 580–6200 kg/ha) than in the nil treatment (640 kg/ha, range 150–1210 kg/ha).

On the brown sodosol, Zn application increased ($P<0.05$) Verano yield from 3560 kg/ha to 5010 kg/ha, only in 1975. In other years, there was no effect of nutrient treatment on legume yield except for the added P treatments (mean yield 5410 kg/ha) which were higher than the minus P treatments (mean yield 1490 kg/ha).

Native grass yields were not influenced by treatments at either site and were consistently low (range 50–1020 kg/ha). Annual species (*Setaria surgens, Panicum mindanaense, Eragrostis basedowii, E. tenellula, Schizachyrium fragile* and *Paspalidium rarum*) were common within the experiments.

Nutrient concentrations. P, N and S concentrations in Verano increased with fertiliser application on both soils. Zn concentrations increased but not until after the first year. Increases in K concentrations with fertiliser application were inconsistent in the first year but of the order of

Table 3. Nutrient concentrations and nitrogen to sulfur ratios of Verano tops in 1975 and the mean of harvests from 1976–1979 in experiment 1 on a grey kandosol (GK) and brown sodosol (BS).

Nutrient	Treatment	Pre-flowering 1975		Flowering to seeding 1975		Flowering to seeding 1976–1979	
		GK	BS	GK	BS	GK	BS
P (%)	Control[1]	0.28	0.12	0.09	0.09	0.10	0.07
	Nil	0.11	0.07	0.05	0.04	0.05	0.04
	LSD ($P=0.05$)[2]			0.03	0.02	0.01	0.01
N (%)	Control	2.27	2.32	1.87	1.82	1.80	1.45
	Nil	2.18	2.11	1.60	1.52	1.39	1.01
	LSD ($P=0.05$)			0.25	NS	0.19	0.12
S (%)	–S[3]	0.14	0.11	0.07	0.13	0.08	0.09
	Control	0.19	0.12	0.11	0.14	0.10	0.08
	Nil	0.13	0.13	0.09	0.13	0.07	0.07
ZN (mg/kg)	–Zn	10	18	7	10	13	8
	Control	28	23	16	11	33	25
	Nil	35	34	26	28	22	21
Cu (mg/kg)	–Cu	5.4	8.1	6.8	11.8	6.5	6.2
	Control	7.5	7.9	6.4	11.7	7.2	6.2
	Nil	11.0	8.6	7.3	10.0	5.1	4.7
K (%)	–K	1.96	1.77	1.00	1.27	1.27	1.34
	Control	2.71	1.91	1.28	1.23	1.47	1.35
	Nil	2.41	2.36	1.33	1.18	1.01	0.90
Ca (%)	+ Ca	1.39	1.31	0.66	1.41	0.96	1.07
	Control	1.36	1.55	0.66	1.32	0.72	1.00
	Nil	1.47	1.41	1.12	1.55	0.85	0.84
Mg (%)	+ Mg	0.43	0.35	0.35	0.41	0.33	0.28
	Control	0.36	0.30	0.32	0.39	0.31	0.26
	Nil	0.33	0.24	0.28	0.28	0.23	0.13
Mn (mg/kg)	+ Mn	224	162	111	156	235	203
	Control	212	159	121	161	222	174
	Nil	216	158	133	179	130	98
N:S	–S	15	21	22	20	20	18
	Control	13	19	16	17	18	21
	Nil	17	16	19	18	20	16

[1] Control nutrients = S + Zn + Cu + K + Mo + P + Fe + Co.
[2] All data without LSDs were bulked across the four replications before chemical analysis.
[3] –S = Control minus S (similarly for other nutrients).

50% after that time. Concentrations were higher at the pre-flowering stage than at flowering and seeding (Table 3). Added S increased S concentration every year on the grey kandosol, but only in the first effective growing season (1975) on the sodosol. The S, Zn, Cu and Ca concentrations declined between 1976 and 1979 on both soils. N concentration (mean 1.90%) was lower when grown without S (1.56% N) and without Zn (1.73%) on the grey kandosol. In 1979, Verano tops had 0.9 mg/kg Co on the sodosol, and 0.03–0.06% Na on both soils. Native grasses consistently had low N (0.70%) and P (0.05%) concentrations.

Fertiliser rate experiment (2)

Dry matter yield. Phosphorus application, as single or triple superphosphate, increased Verano yield in all years. There was an interaction between applied phosphorus and seasonal rainfall on Verano yield. Yield response curves in 1975 and 1976 were similar on both soils, with higher yields in 1976, the year with the higher rainfall. There was negligible yield response to applied phosphorus above 30 kg/ha in either year. In 1977, the year with the longest growing season (6 consecutive months received between 40–237 mm rainfall), Verano yield increased with increasing P rate (to the original 100 kg/ha) on both soils, but to a higher level on the kandosol (Figure 1a) than on the sodosol (Figure 1b).

Both fertilisers gave similar yield increases except in 1975 when single superphosphate produced higher yields than did triple superphosphate at 20, 30 and 60 kg/ha P on the sodosol. In a similar way, adding S to triple superphosphate increased yield only in 1975. In 1979 there were still yield responses to the initial single superphosphate application, but not to triple superphosphate. The original single superphosphate increased ($P<0.05$) Verano yield from 860 kg/ha (nil P) to 3500 kg/ha (60 kg/ha P). Applying an additional 20 kg/ha P as single superphosphate after the fourth year on the grey kandosol, increased ($P<0.05$) dry matter yield over the following growing season from 1450 to 2750 kg/ha.

Over the first 4 years, native grass yields (mean 600 kg/ha) on the grey kandosol were low relative to Verano yields, and declined with increasing legume yield and P rate. In 1979, the fifth year, grass yields were not affected by P rates or the maintenance fertiliser; however, single superphosphate treatments produced more ($P<0.05$) grass (mean 2330 kg/ha) than did triple superphosphate (mean 1460 kg/ha).

Plant nutrient concentrations. On both soils, P concentration in Verano tops increased linearly ($P<0.01$) with increasing P rates for both superphosphate forms (Figure 2, a and b). Maximum P yield on the grey kandosol was 0.4 kg/ha P without applied P and 9.2 kg/ha P with added P (1977), compared with a maximum of 12.2 kg/ha P on the sodosol (1976).

P application increased N concentrations in flowering Verano (Figure 2, c and d). In pre-flowering Verano, S concentration was higher in the single superphosphate treatments (to 0.22%) than in the triple superphosphate treatments (0.16%) or the nil S fertiliser treatment (0.14%). At flowering, S concentrations were increased by single superphosphate for the first 3 years but were not affected by triple superphosphate (Figure 2, e and f). In the first year, adding 10 kg/ha S to triple superphosphate (at 60 kg/ha P) increased ($P<0.05$) S from 0.07% to 0.11%. The native grasses always had lower N (mean 0.7%) than Verano.

On both soils, from 1975–1977, the N:S ratio in Verano tops was lower with single superphosphate (mean 16) than with triple superphosphate (18).

Concentrations of the other nutrients in flowering Verano were similar for the 2 fertilisers on both soils. The mean concentrations over the first 4 years were: K 1.25%, Ca 1.07%, Mg 0.27%, Zn 30 mg/kg, Cu 6 mg/kg and Mn 170 mg/kg. Zinc was lowest (13 mg/kg) with 10 kg/ha P as single superphosphate in the first season.

Applying the single superphosphate top-dressing after the fourth season increased concentrations of both P (from 0.05% to mean 0.09%) and S (from 0.07% to mean 0.10%), but not N (mean 1.42%) in Verano on the grey kandosol in 1979. On the sodosol, the additional superphosphate increased the P concentration for 2 years (from 0.07% to 0.11%), N for one year (from 1.3% to 1.7%), and S for 2 years (0.07% to 0.15%). The N:S ratios were reduced by this additional fertiliser from 25 to 12.

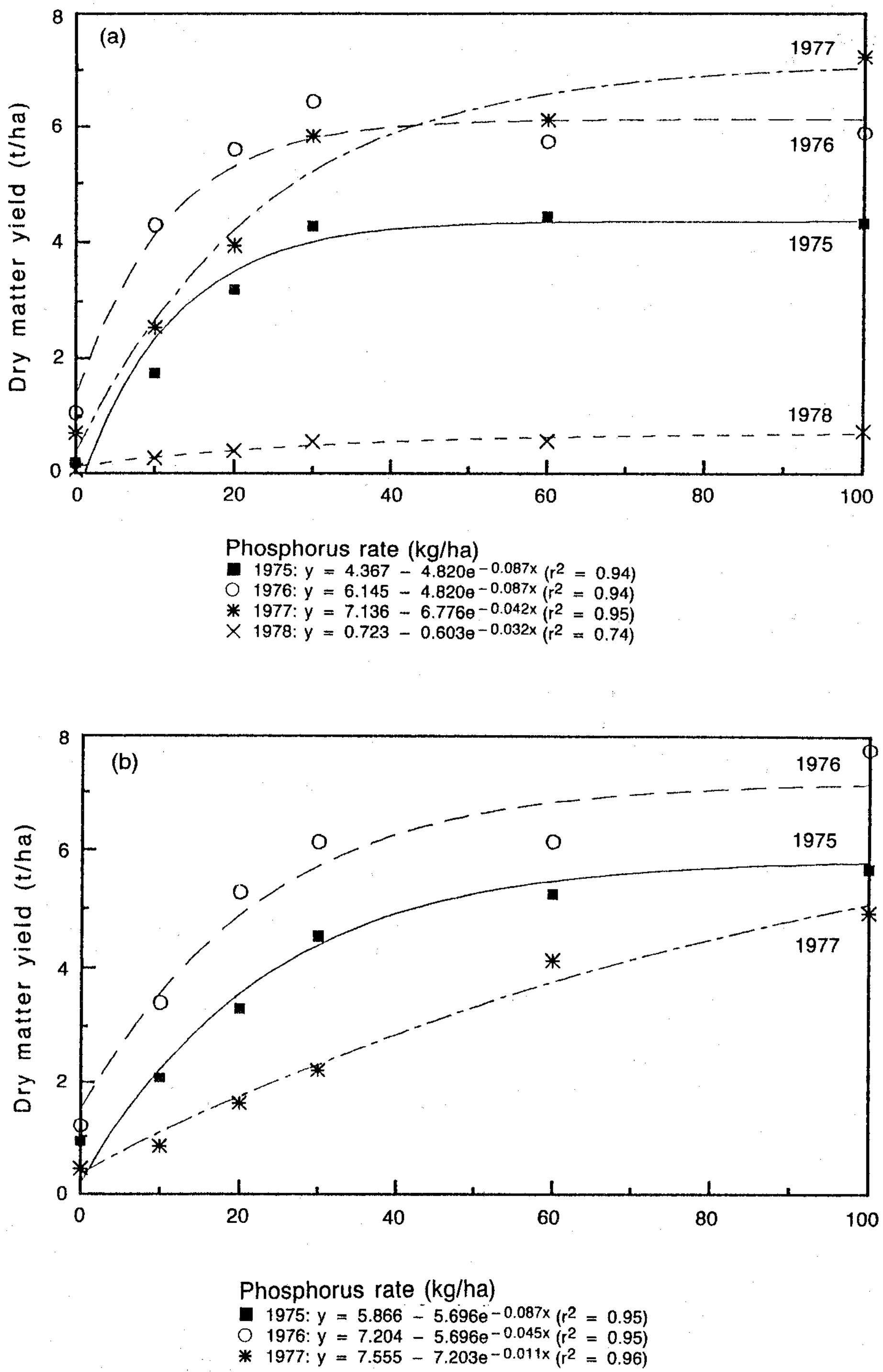

Figure 1. Dry matter yield of Verano at a range of phosphorus rates (means of single and triple superphosphate) on (a) a grey kandosol and (b) a brown sodosol.

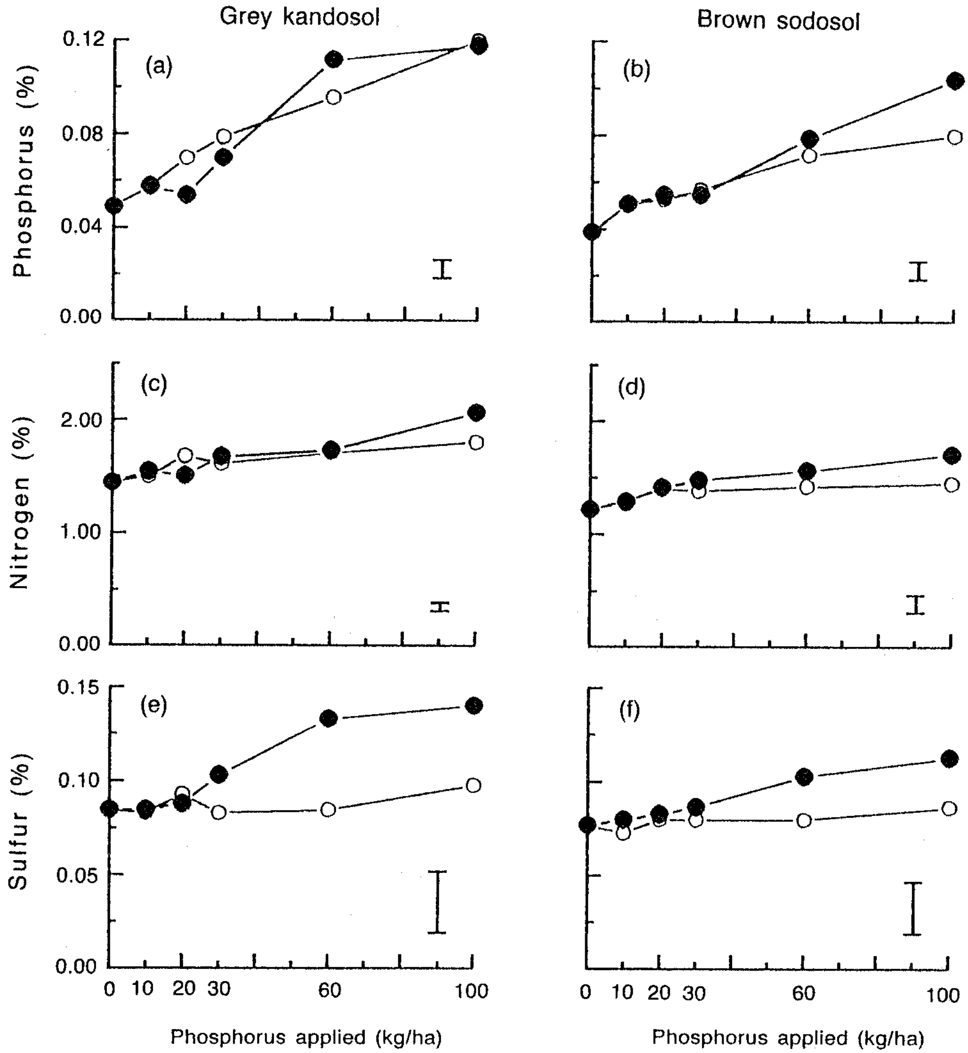

Figure 2. Phosphorus, nitrogen and sulfur concentrations in Verano tops at flowering at a range of phosphorus rates from single (●) and triple (o) superphosphate on a grey kandosol (mean of 4 harvests in 1975, 1976, 1977 and 1978) and a brown sodosol (mean of 3 harvests in 1975, 1976 and 1977). Vertical bars are LSD (P = 0.05).

Soil P. Acid-extractable P in surface (0–10 cm) soil increased from 4 to 30 mg/kg with increasing fertiliser P rates in 1976. Eighty percent of maximum Verano yield in 1976 and 1978 was attained at a soil P level of 8 mg/kg (Figure 3).

Native pasture experiment (3)

Dry matter yield. In the first year, N application significantly ($P<0.05$) and linearly increased dry matter yield (DM yield = 2238 + 19.72N; r^2 = 0.80). Native pasture yields of 2050 kg/ha in the absence of N were increased to a maximum of 3630 kg/ha with applied N. Application of P fertiliser also significantly ($P<0.05$) increased yields (DM yield = 2342 + 54.8P − $0.71P^2$; r^2 = 0.78), from 2310 kg/ha without P to a maximum yield of 3320 kg/ha. In the second year, the N response was significant at P = 0.057 (mean yield 1470 kg/ha). There were no N by P interactions.

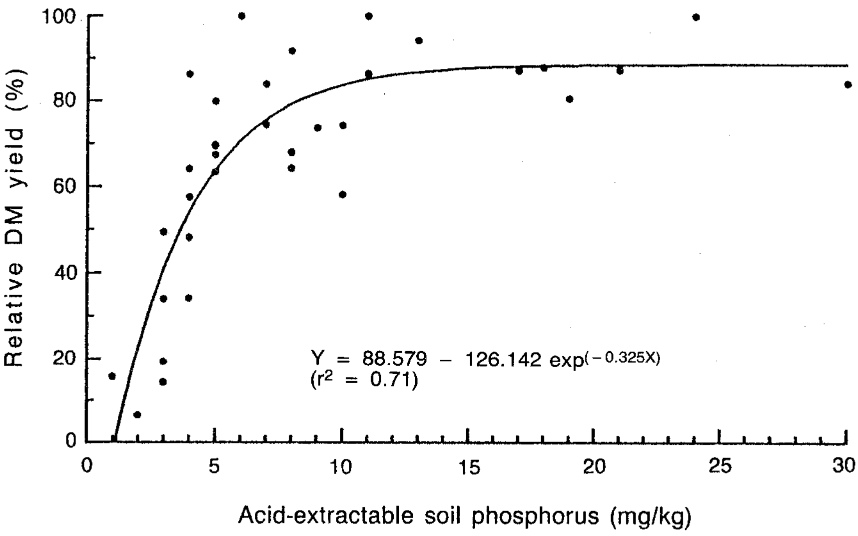

Figure 3. The relationship between relative dry matter yield of Verano tops at flowering (expressed as a percentage of maximum yield each year) and acid-extractable phosphorus in the surface (0–10 cm) of a grey kandosol in 1976 and 1978, and a brown sodosol in 1976.

Nutrient concentrations. Single superphosphate application increased ($P<0.05$) P concentrations from 0.03% to 0.12% in year 1 and 0.09% in year 2, and S concentration from 0.07% to 0.10% in the first year. The N fertiliser had no effect on nutrient concentrations. At the end of the first summer, mean concentrations were: 0.5% N, 0.08% P, 0.82% K, 0.09% S, 0.35% Ca, 0.15% Mg and 0.02% Na. Yields (kg/ha) of N, S, K, Ca and Mg all increased significantly ($P<0.05$) in response to both applied N and P fertilisers in the first year. P yield increased only to P fertiliser.

Botanical composition. At the highest N rate in the first year, the proportion of *S. fragile* declined from 50% (on a dry matter basis) at nil P to 3% at 60 kg/ha P, and there was an increase ($P<0.05$) in *C. fallax* with increasing P rate in both years (from 18% to 42%). Across all treatments during the first 2 years, *C. fallax* declined (mean of 40% to 24%), as did minor annual grasses (14% to 2%), while there was an increase in *Aristida* spp. (23% to 33%) and *S. fragile* (21% to 39%). Forbs, mainly *Polymeria ambigua* and *Galactia tenuiflora*, comprised 2% in both years.

Discussion

Verano response to fertilisers

Phosphorus and, to a lesser extent sulfur, increased Verano yield on these light-textured soils of north-west Queensland. These soils are very deficient in P and Verano required 8 mg/kg acid-extractable soil P to produce 80% of maximum yield. This soil P level agrees with the P level required for maximum cattle production in northern Australia (Kerridge *et al.* 1990). Applying 30 kg/ha P on these soils improved legume growth and the response lasted for 5 years. After this period a further 20 kg/ha P (200 kg/ha superphosphate) increased yield and nutrient concentrations.

The commercial practice of applying 100 kg/ha of superphosphate every 3–5 years or even less often, gives less than half the potential legume yield in most years and has little effect on N or P concentrations in Verano. At this low fertiliser rate, P concentration may be inadequate for cattle growth and lactation (McDowell *et al.* 1983). In particular, breeders would need a P supplement to gain most benefit from the legume. An alternative to applying this low rate is to add 300 kg/ha of single superphosphate initially which would improve legume growth for 5 years. This would also reduce the need for supplements and lead to less frequent maintenance fertiliser. A further 200 kg/ha superphosphate after 5 years would again increase legume growth and quality.

The soil P level of 8 mg/kg required by Verano is similar to that required by Seca shrubby stylo which produced 80% of maximum yield at 7 mg/kg P on a sandy red earth soil in north Queensland (Gilbert and Shaw 1987). This supports the finding of Probert and Jones (1982) that Verano would not respond to added P on a red duplex soil with 12 mg/kg P.

On the sodosol, there were no yield responses to nutrients in the first season (mean 190 kg/ha) or in 1978 (mean 380 kg/ha) when waterlogging and drought, respectively, restricted Verano establishment or regeneration and growth. Low production from poorly developed plants on both soils in 1978 reflects the short, 2-month, growing season. Yield response by Verano was related to both wet season (November–April) and annual (July–June) rainfall in 1975 and 1976 on both soils, and the maximum yield was higher in the higher rainfall year of 1976. In the long growing season of 1977 (November–April), Verano growth was probably limited by soil phosphorus as the yield continued to increase to the maximum rate applied.

Fertiliser increases Verano quality

Phosphorus and sulfur fertiliser increased Verano quality on both the sodosol and kandosol. Without fertiliser, P and S concentrations were low and would have limited animal production. Since S is consistently low and insufficient to maintain cattle liveweight by NRC (1976) standards, the increased S in Verano after adding S with a P fertiliser could give a significant increase in animal performance on these pastures. The high N:S ratios, with a low S concentration in Verano also indicate S deficiency for animal nutrition (Moir *et al.* 1967–1968). Although triple superphosphate costs 25% less than single superphosphate for the same rate of P distributed, this saving may not cover the cost of additional supplements required to compensate for the lower quality of feed produced. Single superphosphate is recommended because it increases yield and quality to a greater extent.

Soil analyses also indicated S, as well as the P deficiency, could limit Verano growth, particularly on the grey kandosol. On this soil, phosphate-extractable S was less than the critical value of 4 mg/kg (Probert and Jones 1977). However, on the sodosol, Verano yield responses to applied S in the field were less than those of *S. humilis* to S in pot experiments on this soil (Webb 1975). The lack of a S response in the first year may be due to cultivation at sowing. Although S is deficient in the surface there is accumulated S at depth. Verano roots may exploit this S below 60 cm (Probert and Jones 1982) to increase growth, but not sufficiently to give adequate plant S levels.

Zinc concentrations in Verano without added Zn (7 mg/kg) were low for both plant growth (Chapman 1966) and grazing animals (McDowell *et al.* 1983). Low Zn in surface soil limited Verano growth in the first year, but not subsequently, when perennial plants may have exploited higher Zn levels (115 mg/kg total Zn at 50 cm) down the profile. An increase in yield with Zn application in the first year has been reported with *S. humilis* on a grey earth (kandosol) in this region (Bishop 1974).

Calcium was marginal (0.66%) for plant growth (Probert 1980) and may limit animal production on these pastures. Levels were similar to those reported in stylo pastures at Katherine, where Ca deficiency was suspected of contributing to poor cattle performance in the dry season (McLean *et al.* 1990). On these soils, Verano had adequate K (average 1.40%) (Winter and Jones 1977), Mn (180 mg/kg) (Chapman 1966) and Mg (0.3%) (Little 1982). Na was low to marginal (to 0.06%) (McDowell *et al.* 1983). Mo also appeared adequate as Verano nodulated, was a healthy green colour when fertilised with P, S and Zn, and did not increase in yield to added Mo.

Native pasture response to fertilisers

Without competition from Verano, both N and P fertilisers at high rates increased dry matter and nutrient yields of these grasses, and the superphosphate fertiliser also increased P and S concentrations. The increase in P concentration, but not in N, resulting from superphosphate addition was similar to the grass response in a Townsville stylo pasture reported by Jones (1968). The low rates of superphosphate accepted commercially caused no responses in these grasses. However, the Verano experiments show there can be more N present in plant tops in an adequately fertilised legume pasture (to 153 kg/ha) than the highest N rate (75 kg/ha) applied in the native pasture experiment. This suggests the annual decomposition of organic N in well fertilised Verano pastures could provide sufficient N to promote annual grasses as has occurred in more favourable climatic environments such as at 'Wrotham Park' near Chillagoe in north Queensland (T.J. Hall and R.W. Walker, unpublished data) and with fertilised *S. humilis* pastures in coastal north Queensland (Winks *et al.* 1974).

The significant contribution of the normally infrequent annual grasses in the first year of the native pasture experiment show these species respond rapidly to increasing soil fertility. A similar response also occurred in the Verano experiments in the high rainfall year of 1979. Although a glasshouse study (McIvor 1984) indicated that the perennial *C. fallax* had a low P requirement, the present study demonstrates that this species responds to high rates of superphosphate in the absence of stylo competition or wet season grazing. However, the high grazing pressure imposed on some fertilised stylo pastures would be expected to remove this species in several years, irrespective of fertiliser management.

Since high fertiliser rates are needed to improve grass quality on these soils, applying fertilisers is not an economic option for improving animal production. Either direct P supplementation or adding a legume plus P fertiliser is necessary. These requirements are similar to other areas of light-textured soils across northern Australia, where the responses of native and stylo pastures (Jones 1990) and of cattle (Winter *et al.* 1990) to P have recently been reviewed.

Conclusion

Phosphorus fertiliser gives high yields of Verano on the 2 light-textured soils. An initial 30 kg/ha P gives near maximum yield, with yield and quality benefits lasting 5 years. Since the grey kandosol is very S deficient, single superphosphate (high S analysis) is recommended over triple superphosphate (low S form), as the additional S supplied to the legume improves forage quality. No other fertilisers are needed for adequate Verano growth, although adding Zn gives a greater yield in the first year.

Verano stylo is well suited to these light-textured soils of north-west Queensland, and when adequately fertilised, or the cattle are directly supplemented with P, large gains in cattle production can be expected (Kerridge *et al.* 1990). Native annual grasses respond to improved fertility, but production is limited by legume competition.

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