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Soils on which buffel grass seedlings respond to phosphate fertiliser

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Summary

Eleven western Queensland soils were tested to identify those on which buffel grass (*Cenchrus ciliaris*) seedling growth would be strongly enhanced by the presence of phosphate fertiliser. The addition of 26 kg P/ha to the surface of fertile, cracking clays and alluvial soils did not markedly improve seedling growth rate, but a large positive response was achieved on four acid red earths, on a grey loam and on a loose sandy soil. All three buffel strains used (Biloela, Gayndah and Q10087) responded similarly.

INTRODUCTION

Buffel grass (*Cenchrus ciliaris* L.) is normally sown in western Queensland without applying fertiliser. It is easily established on dark, fertile clay soils and readily invades high fertility areas (e.g. sheep yards). However, on infertile mulga soils (red earths) seedling growth is very slow (Silcock 1980) and buffel grass is difficult to establish. Christie (1975*a*) showed that buffel grass growth was greatly improved by phosphate fertiliser on mulga soils, but only after phosphorus deficiency was alleviated were other nutrient responses achieved. After phosphorus, nitrogen was the next most limiting nutrient and sulphur levels were marginal, but no other macro- or micro-nutrients were limiting buffel grass seedling growth on these soils. Christie estimated that buffel grass seedlings would respond well to applied phosphate where available soil phosphorus (BSES O.1N acid extraction - Kerr and von Stieglitz 1938) is below 25 ppm. Phosphate concentrations of many soils in western Queensland fall well below this value (Dawson and Ahern 1974). Hence it would be expected that seedlings of buffel grass would establish more readily on many western Queensland soils if phosphate fertiliser was applied.

Broadcast application of phosphate is not economical in western Queensland. However, it may be beneficial and economical to sow phosphate-coated buffel grass seed on these soils (Silcock and Smith 1982). It is not known if Christie's value of 25 ppm applies to all soils, and this aspect was examined in a pot experiment. Three strains of buffel grass were grown, with and without added phosphate, on eleven important soils collected from south-western and central-western Queensland to determine which ones would not justify the application of phosphate when sowing buffel grass.

MATERIALS AND METHODS

Dry surface soil (0 to 10 cm) was collected from eleven sites in western Queensland between Barcaldine and Wyandra (Table 1). The soil was sieved on site through a 3 mm sieve and transported to Charleville. Each soil was then assessed for its moisture content at field capacity using the drained column technique (McIntyre 1974)(Table 1). Their capacity to swell when wetted was also noted. Six pots of *c.* 24 cm top diameter and 21 cm deep were filled to an appropriate depth with each dry soil so that the pot would be almost filled when the soil was wet. The resulting weight of oven-dry soil for each field site is shown in Table 1. The soils were then brought to field capacity by weight with rain-water and allowed to equilibrate for seven days. Appropriate amounts of water were added each day to replenish that lost by evaporation (about 200 mL) and emerging weed seedlings were removed.

Table 1. Location, site and some physical characteristics of the eleven soils used. Wet soil volume was similar in all pots

Code	Soil type	Location	WARLUS* Land unit	O.D. Weight per pot (kg)	Moisture content at field capacity (%)
WA	Black, cracking alluvial clay-Ug5.17† (Warrego Alluvium)	3 km N of Charleville	WARLUS III Unit W6 (A02)	8.80	25.5
NA	Grey, self-mulching clay-Ug5.26 (Northern *Astrebla*)	35 km ESE of Blackall	WARLUS IV Unit 1	7.54	39.1
G	Stony, brown, self-mulching clay-Ug5.31 (Gidyea)	30 km S of Blackall	WARLUS IV Unit 15 WARLUS II Unit 39	8.13	31.5
SA	Grey-brown, cracking clay-Ug5.34 (Southern *Astrebla*)	8 km W of Wyandra	WARLUS III Unit A1 (A04)	8.71	30.7
HB	Grey colluvial, sandy clay-loam-Dr2.12 (Heavy Box)	25 km SE of Charleville	WARLUS III Unit B1 (B01)	10.29	16.5
CP	Coarse, light coloured sand-Uc1.23 (Cypress Pine)	2 km N of Charleville	WARLUS III Unit D3 (S05)	13.14	8.0
D	Red sandy earth-Uc1.43 (Desert)	30 km SSE of Barcaldine	WARLUS IV Unit 47	13.13	8.5
SB	Sandy red earth-Gn2.12 (Sandy Box)	65 km SSE of Charleville	WARLUS III Unit M3 (M15)	12.32	10.3
NM	Red earth-Gn2.12 (Nebine Mulga)	50 km SSE of Charleville	WARLUS III Unit M2 (M01)	11.00	15.4
CM	Sandy red earth-Uc1.43 (Charleville Mulga)	5 km E of Charleville	WARLUS III Unit S1 (M03)	12.30	10.1
HM	Stony red earth-Um1.43 (Hard Mulga)	45 km WSW of Charleville	WARLUS III Unit H2 (H01)	12.49	12.8

*WARLUS=Western Arid Region Land Use Study (See Dawson and Ahern 1974)
†Northcote classification (See Northcote 1971)

Before sowing the buffel grass seeds on the seventh day (4 February 1980) two phosphate treatments (equivalent to 0 and 26 kg P/ha on a pot surface area basis) were applied and replicated three times for each soil, the 22 pots (11 soils×2 P treatments) being randomised within each of the three blocks. The fertilizer was applied as KH_2PO_4 (462.2 mg per pot) by spreading 200 mL of solution over the pot surface. Potassium was chosen as the cation carrier for several reasons. Very few Australian soils respond to potash fertilisers when growing pasture grasses and numerous chemical analyses have rarely shown potentially deficient levels in western Queensland soils.

Furthermore, neither a potassium deficiency nor any P×K interaction was detected in previous pot trials using potassium dihydrogen orthophosphate on mulga soils (Christie 1975a; Silcock and Smith 1982). Subsequent chemical analyses (Table 2) also support this result in the case of the soils used in this experiment, with the possible exception of CP (0.13 meq K^+ per 100 g) (Leslie 1963).

Caryopses of three buffel varieties (Gayndah, Q10087 and Biloela) were sown at about 5 mm depth in a fixed pattern in each pot, seven sites per pot for each strain and two caryopses per site. The surface soil was then kept moist for the next five days by spraying regularly with rain-water. Thereafter pots were watered each afternoon to field capacity by weight. Seedlings were thinned to one per sowing site where necessary.

The following data were recorded for each seedling:

1. Hours to emergence (twice daily)
2. Days to appearance of leaf 3
3. Days to full expansion (i.e. ligule visible) of leaves 3, 4 and 5
4. Length of the leaf lamina of leaves 3 and 4
5. Mid-leaf width of the lamina of leaf 4

Once seedlings had 5 fully expanded leaves, all but 2 plants of each variety in each pot were removed so that tillering could proceed with minimal root competition. For each remaining plant, the date of first tillering and the position of the tiller were recorded. The trial was terminated after 38 days.

Samples were kept of the original sieved soils and also from the surface 3 cm of each pot after the trial concluded. These were analysed for mechanical and fertility parameters using the methods outlined by Ahern (1974) and Lindsay and Norvell (1978).

RESULTS

The properties of the soils are summarised in Table 2 along with those of a representative soil from beneath poplar box trees (*Eucalyptus populnea*) growing on mulga soil. Buffel grass regularly colonises the area under box trees in thinned mulga country (Christie 1975*b*). The gidyea soil (G) where buffel grass grows best, was alkaline, rich in phosphorus and calcium and had a comparatively high content of soluble salts. The very clayey soils (G, NA and SA) were neutral to alkaline and relatively fertile, apart from the southern *Astrebla* grassland soil (SA). On two of the mulga soils (CM and HM) exchangeable aluminium was a significant proportion of the total exchangeable cations (Table 2). Soil type did not significantly affect seedling emergence except that seedlings emerged slightly later on the SA soil ($P<0.05$) (data not presented).

All three buffel varieties responded similarly to phosphate fertiliser. Phosphate had no significant effect on seedling growth on WA, NA and G soils and only a slight ($P<0.05$) early effect on SA soil. Buffel grass responded strongly ($P<0.01$) to phosphate in the early seedling stages on all other soils (Table 3). The size of the phosphate response was closely related to the original pH and available P status of the soils. Once the early P deficiency had been overcome, only the hard mulga soil (HM) showed any marked difference from the other fertilised, acidic soils in earliness of tiller production (Table 3). However, the mulga soils generally produced the first tiller in the axil of leaf 3 while the clay soils had the first tiller arise often from the axil of leaf 2.

The buffel varieties differed significantly ($P<0.01$) in their earliness to tiller irrespective of fertiliser, with Gayndah averaging 23.3 days, Q10087 25.8 days and Biloela 26.3 days from sowing. All three varieties produced their first tiller from a similar node, but this node's position was affected by soil type and phosphate. In the absence of phosphate, seedlings on infertile soils exserted the first tiller from the axil of leaf 4 more often than leaf 3. Leaf size as well as appearance rate increased after leaf 2 in response to added phosphorus on the less fertile soils.

Univariate regression analysis (linear, quadratic, and power functions) showed that seedling growth rate of buffel grass was most closely related to soil pH (linear $R^2=0.75$) and available soil phosphorus ($R^2=0.81$). Multivariate analysis did not improve the correlation between soil and plant growth parameters. Below about 20 ppm available soil P, seedling growth was very sensitive to increases in available P while above this level

Table 2. Physical and chemical properties of the original sieved surface soil samples from 11 sites, plus soil from beneath poplar box trees. Methods as in Ahern (1974) and Lindsay and Norvell (1978)

Soil	Particle sizes (%)				pH (1:5)	E.C. (mS/cm)	Cl (ppm)	Extr. Acid	P ppm Bicarb	Exch. cations (meq per 100 g)						DTPA	(ppm)	
	CS	FS	S	C						Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Al^{+++}	Fe	Cu	Mn	Zn
WA	37	23	11	29	6.8	.049	24	>120	76	13.1	5.5	0.1	0.90	0.5	34	1.6	46	1.2
NA	2	19	21	59	8.0	.056	9	>120	33	36.3	3.8	0.6	1.57	1.4	6	1.4	10	0.4
G	7	35	12	47	8.3	.195	37	120	49	38.4	5.9	0.2	1.65	1.2	2	1.4	10	0.8
SA	9	28	14	50	7.5	.041	26	17	12	11.5	6.3	1.3	0.87	0.5	13	1.7	58	0.9
HB	23	39	6	29	5.9	.022	6	8	11	4.5	1.8	0.1	0.78	0.2	28	1.0	56	0.8
CP	56	38	1	5	6.1	.018	11	17	15	1.0	0.3	0.1	0.13	0.1	4	0.2	16	0.3
D	45	45	2	8	6.2	.022	12	4	5	1.5	0.5	0.1	0.23	0.1	4	0.3	14	0.2
SB	45	38	1	14	5.5	.016	10	5	5	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.
NM	30	38	6	27	4.7	.044	17	4	4	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.	n.c.
CM	44	39	3	14	5.3	.017	10	5	6	0.7	0.1	0.1	0.32	0.6	30	0.9	30	17.0
HM	20	54	6	18	5.2	.017	11	4	4	1.2	0.4	0.1	0.65	0.5	9	0.4	20	0.3
Box	n.c.	n.c.	n.c.	n.c.	6.5	.069	25	20	n.c.	4.1	1.1	0.1	0.62	0.2	6	0.6	105	5.0

n.c.=data not collected

no clear trend existed (Figure 1). Clay content, available P and pH are clearly related in the 11 soils chosen (Table 2). Hence separation of their relative importance to seedling growth is not possible from this experiment.

Table 3. Effect of phosphate fertiliser (26 kg P/ha) on seedling growth of buffel grass (*C. ciliaris*) on eleven different soils. Results are means of 3 varieties, Gayndah, Q10087 and Biloela

Soil	Days from sowing to full expansion of Leaf 4			Days from full expansion L4 until first tillering		
	−P		+P	−P		+P
WA	14.0		13.4	3.1		2.8
NA	14.1		13.8	4.1		3.6
G	14.5		13.8	4.6		3.6
SA	15.2	*	13.6	8.8	*	4.2
HB	17.9	**	13.8	8.9	*	4.4
CP	16.1	**	13.6	8.4	*	4.4
D	19.8	**	13.8	12.1	*	6.3
SB	22.4	***	14.5	21.3	***	7.5
NM	23.4	***	13.9	25.4	***	6.3
CM	25.7	***	14.1	19.1	***	6.4
HM	30.6	***	14.8	20.4	**	10.3
(l.s.d. 0.05=1.3)					(l.s.d. 0.05=3.3)	

*$P<0.05$ **$P<0.01$ *** $P<0.001$

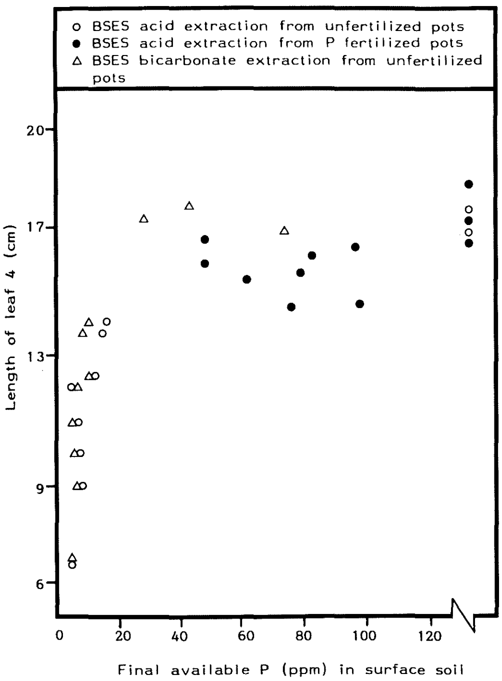

Figure 1. The relationship between the mean length of leaf 4 of the 3 buffel varieties and the concentration of available phosphorus extracted from the surface 3 cm of 11 different soils after the trial.

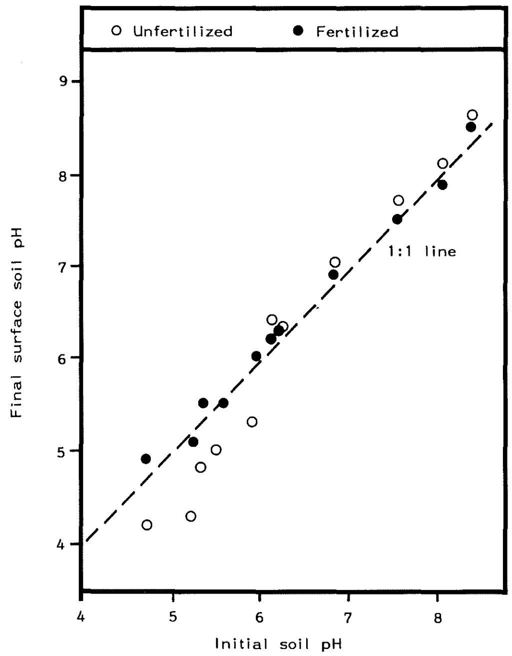

Figure 2. The relationship between the original soil pH (1:5 in water) of 11 different soils and the final surface pH of fertilised and unfertilised pots of these soils. The pH of the rainwater used to water the pots averaged 6.2.

The surface soil pH changed during the trial where no phosphate was added. The acid soils became more acid and the neutral to alkaline ones appeared to become more alkaline (Figure 2). No soil pH changes occurred where potassium phosphate was added to the soil surface.

DISCUSSION

A great improvement in seedling growth of most buffel grasses can be expected where phosphate fertiliser is applied to all but the most fertile soils in western Queensland. The mulga soils were the most responsive but even cypress pine sands, where buffel naturally establishes fairly easily, should benefit. Where seedling growth is accelerated, establishment success should also improve as rooting depth and tiller production should increase along with shoot growth. Once buffel seedlings have tillered, phosphate is probably no more limiting for growth than nitrogen or pH except on the most acidic, infertile soils. Thus, phosphate pelleted buffel seed merits trial on most sandy, acidic soils in Queensland, not just mulga soils (Silcock and Smith 1982). Such pelleted seed is not expected to improve buffel establishment on gidyea soils.

Buffel grass is very sensitive to excessive amounts of aluminium in the soil solution (Spain and Andrew 1978) and aluminium toxicity is a potential problem if the soil pH falls below about 5.5 (Sanchez and Salinas 1981). Below this, aluminium becomes increasingly soluble in the soil solution (Rorison 1973) and may affect sensitive species such as buffel.

The 4 mulga soils (SB, NM, CM and HM) are all acidic enough for aluminium to be a problem if sufficient exists in the soil matrix. Over 15% aluminium saturation of the exchangeable cation capacity can be regarded as potentially toxic (Cregan 1980), particularly where exchangeable calcium is below 4 meq per 100 g. As all the acidic soils in this trial had low exchangeable calcium levels, 33% and 17.5% aluminium saturation in the CM and HM soils respectively is potentially toxic. On all mulga soils the unfertilized buffel seedlings showed some aluminium toxicity symptoms e.g. slow growth, limited lateral root growth, dark coloured seminal roots and early necrosis of the leaves. However, these could also be symptoms of phosphorus or calcium deficiency so the occurrence of aluminium toxicity on mulga soils is not proven by this experiment. Where available phosphorus is adequate, aluminium toxicity seems to be of minimal importance.

It is of interest that the naturally amended mulga soil from beneath poplar box trees where buffel grows readily, had only 3.3% of the cations contributed by aluminium, a pH of 6.5 and a moderate level (20 ppm) of available phosphorus (Table 2).

The emergence of the first tiller at a higher leaf axil on less fertile soils confirms results reported for *Anthephora pubescens* (Silcock and Smith 1982). Such a delay, allied with a slower rate of leaf appearance on such soils, must seriously hamper seedling establishment of buffel grass. Buffel grass seedlings have 2 roots at most, for anchorage and for gathering water and nutrient supplies, before establishing adventitious roots.

As the interpretation of the results of this trial are confounded by the close correlation between pH, available P and soil clay content, further trials seem warranted to determine whether available P or pH or percentage saturation of exchangeable cations by aluminium or calcium is the major factor limiting buffel grass seedling growth on a wide spectrum of soils in tropical Australia.

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References

Ahern, C.R. (1974), Soil analytical methods, in *Western Arid Region Land Use Study-Part 1*, Queensland Department of Primary Industries, Division of Land Utilization Technical Bulletin No. 12, Appendix IV.
Christie, E.K. (1975*a*), A study of phosphorus nutrition and water supply on the early growth and survival of buffel grass grown on a sandy red earth from south-west Queensland, *Australian Journal of Experimental Agriculture and Animal Husbandry* **15**, 239-49.
Christie, E.K. (1975*b*), A note on the significance of *Eucalyptus populnea* for buffel grass production in infertile semi-arid rangelands, *Tropical Grasslands* **9**, 243-46.
Cregan, P.D. (1980), *Soil acidity and associated problems-Guidelines for farmer recommendations*, Department of Agriculture, NSW Agbulletin 7.
Dawson, N.M. and Ahern, C.R. (1974), Soils, in *Western Arid Region Land Use Study-Part 1.* Queensland Department of Primary Industries, Division of Land Utilization Technical Bulletin No. 12.
Kerr, H.W. and von Stieglitz, C.R. (1938), *The laboratory determination of soil fertility*, Queensland Bureau of Sugar Experiment Stations Technical Communication No. 9.
Leslie, J.K. (1963), Nutrient responses on a cypress pine sand, *Queensland Journal of Agricultural Science* **20**, 191-94.
Lindsay, W.L. and Norvell, W.A. (1978), Development of a diethylenetriamine-penta-acetic acid soil test for zinc, manganese and copper, *Soil Science Society of America Journal* **42**, 421-28.
McIntyre, D.S. (1974), Water retention and the moisture characterictic, in J. Loveday ed. *Methods for Analysis of Irrigated Soils*, CAB Commonwealth Bureau of Soils, Technical Bulletin No. 54.
Northcote, K.H. (1971), *A Factual Key for the Recognition of Australian Soils*, 3rd edition Rellim:Glenside, S. Australia.
Rorison, I.H. (1973), The effect of extreme soil acidity on the nutrient uptake and physiology of plants, in H. Dost ed. *Acid Sulphate Soils, I. Introductory papers and bibliography*, International Institute for Land Reclamation and Improvement, Wageningen.
Sanchez, P.A. and Salinas, J.G. (1981), Low input technology for managing oxisols and ultisols in tropical America, *Advances in Agronomy* **43**, 280-407.
Silcock, R.G. (1980), Seedling growth on mulga soils and the ameliorating effects of lime, phosphate fertilizer and surface soil from beneath poplar box trees, *Australian Rangeland Journal* **2**, 142-50.
Silcock, R.G. and Smith, Flora T. (1982), Seed coating and localized application of phosphate for improving seedling growth of grasses on acid, sandy red earths, *Australian Journal of Agricultural Research* **33**, 785-802.
Spain, J. and Andrew, C.S. (1978), Mineral characteristics of species. Responses of tropical grasses to aluminium in water culture, in *Division of Tropical Crops and Pastures Annual Report 1976-77*, CSIRO, Australia.

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