NUTRIENT STUDIES ON SOME SOILS FROM EUNGELLA AND EAST FUNNEL CREEK, MACKAY HINTERLAND, QUEENSLAND

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ABSTRACT

The plant nutrient status of four gradational soils developed on acidic to basic igneous parent material was assessed in pot culture experiments using Trifolium repens *as the test plant. There were large responses to phosphorus, molybdenum, potassium, sulphur and liming and small responses to copper and magnesium, but the number and extent of deficiencies varies greatly on the four soils. Field experiments at two of the sites with* Desmodium intortum *cv. Greenleaf —* Setaria anceps *cv. Nandi and* Glycine wightii *CPI 28279 —* S. anceps *cv. Nandi as the test pastures showed responses to phosphorus, molybdenum and potassium. Establishment and persistence were good for* D. intortum *but poor for* G. wightii.

INTRODUCTION

The Eungella Tableland is situated 80 km west of Mackay in the Clarke Range and the East Funnel Creek area is 50 km south of Mackay in the associated Conners Range. The areas lie at approximately 21° S latitude and at an altitude of 600 to 1000 metres. Soils are mainly gradational becoming more acid with depth (Isbell *et al.* 1967). The geology of the area has been described by Jensen (1964). Average annual rainfall varies from 1500 to 3000 mm. Rainforest was the dominant vegetation but dairying on naturalised or sown pastures is now the main form of land use (Allen 1965).

The need for fertilization of pastures is recognized although there is little information on specific nutrient deficiencies. Goodchild (1960) obtained a large response by a kikuyu (*Pennisetum clandestinum*), paspalum (*Paspalum dilatatum*), mat grass (*Axonopus affinis*) pasture to 500 kg ha^{-1} of a 10:10:0 NPK fertilizer but oversown white clover (*Trifolium repens*) did not persist. In other experiments and demonstrations, phosphorus responses have been obtained in all areas except at Bee Creek and on a small area of krasnozem soil on basalt (unpublished results, Department of Primary Industries). No responses were obtained to potassium or trace elements. Farmers have established tropical legume-grass pastures successfully using 500 kg ha^{-1} molybdenized superphosphate in all areas except Dalrymple Heights.

The purpose of this study was to define more clearly the nutrient deficiencies of the main soil types in the area. Pot experiments were conducted on representative soils to determine nutrient deficiencies. Field experiments were then established at two sites to verify the pot culture results.

MATERIALS AND METHODS

Pot experiments

Soil samples from 0-10 cm were collected from East Funnel Creek and from Bee Creek, Crediton and Dalrymple Heights on the Eungella Tableland in May 1969. The average annual rainfall in these areas is approximately 1500, 1500, 1800 and 2800 mm respectively. The sites from which the samples were collected had been cleared for over 30 years and had not been fertilized. Chemical analyses for composite surface samples are given in Table 1.

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TABLE 1

*Soil chemical data (0-10cm) on soils used for pot culture experiments**

Location	Parent Material	Soil Type	pH	Avail. P (ppm)	Exchangeable Cations				
					Ca	Mg (me/100g)	K	Na	H
Bee Creek	Basic Intrusive	Gn3.21	5.8	2940	14.6	3.4	0.28	0.39	9.0
East Funnel Creek	Andesite	Gn3.91	5.5	26	11.1	2.7	0.30	0.44	6.9
Crediton	Granite	Gn3.74	4.9	8	4.3	3.3	0.57	0.26	9.1
Dalrymple Heights	Granodiorite	Gn3.74	4.7	6	2.1	0.9	0.20	0.12	15.1

* pH – soil: 0.01N $CaCl_2$ in the ratio 1:5; P-0.01 N H_2SO_4; Ex. bases – 1N NH_4 Cl at pH 4.7; Ex.H at pH 7 with p-nitrosophenol-lime buffer.

Two experiments were conducted on each soil:

Experiment 1. Four rates of phosphorus and the addition or omission of potassium, sulphur, molybdenum and lime in a 4 x 2^4 factorial arrangement; single replication; basal application of magnesium, copper, zinc, boron and cobalt.

Experiment 2. The addition or omission of magnesium, copper, zinc, boron, cobalt, and lime in a ½ x 2^6 factorial arrangement. Phosphorus, potassium, sulphur and molybdenum were applied in a basal application.

White clover (*Trifolium repens* cv. Ladino) was grown as the test species because the experiments were carried out in the winter months at Brisbane. A previous study had shown that while *T. repens* was more responsive to liming than *D. intortum cv.* Greenleaf, response to phosphorus, potassium and molybdenum was similar for the two legumes (Kerridge *et al.* 1972). Pot culture methods were the same as described in this previous study. Seed was inocultated with a commercial *Rhizobium* inoculant. The quantity (g pot^{-1}) and form in which nutrients were applied were:

$Ca(OH)_2$, 1.8; $MgCO_3$, 0.16; $CuSO_4.5H_2O$, 0.014; $ZnSO_4.7H_20$, 0.02; $CoCl_2.6H_20$, 0.0014; H_3BO_3, 0.005; $(NH_4)_6Mo_70_{24}.4H_20$, 0.0013; K_2SO_4, 0.16 (Expt. 2); $KHCO_3$, 0.18 (Expt. 1); $CaSO_42H_20$, 0.12 (Expt. 1); $CaH_4(PO_4)_2.H_20$, 0.94 (Expt. 2), 0, 0.13, 0.38, 1.12 (East Funnel Creek, Expt. 1), 0.15, 0.31, 0.63, 1.26 (other soils in Expt. 1: a nil rate with basal K, S and Mo, but not lime, was also included for these soils).

(1g pot^{-1} = 800 kg ha^{-1}, surface area basis)

Lime was mixed throughout the soil. The other nutrients were added in solution or suspension to the soil surface and mixed into the top 2-3 cm after the soil surface had dried out. Pots were watered to weight (= pF2) with double deionized water.

Plant tops were harvested at 10 weeks of age, dried at 70° C, and weighed for dry matter yield. Plant analyses for nitrogen were carried out on selected treatments by the method of Williams and Twine (1967).

Field experiments

Field experiments were conducted at Crediton and Dalrymple Heights on the same sites sampled for pot experiments. These two sites were selected for field experiments because there had been some difficulty in growing legumes on similar soils in the two localities. Both soils are xanthozems, the most extensive soil group on the Eungella Tableland. The experimental areas, which were mat grass dominant, were first cultivated in October 1969 and sown at the end of January 1970 with the legumes, *Desmodium intortum* cv. Greenleaf and *Glycine wightii* CPI 28279, with *Setaria anceps* cv. Nandi as the companion grass species. Greenleaf desmodium was used because it was already widely grown and *G. wightii* CPI 28279 as it had shown promise as an alternative species in the area. The legume seed was inoculated with commercial *Rhizobium* inoculants.

Each experiment consisted of a $^1/_2 \times 2^6$ factorial arrangement confounded into four blocks. Plot size was 5 m x 5 m. The treatments were:

Crediton: The addition or omission of potassium, sulphur, copper, zinc and molybdenum and either legume. Phosphorus was applied to all treatments.

Dalrymple Heights: Two levels of phosphorus and the addition or omission of potassium, sulphur, copper and zinc and either legume. Molybdenum was applied to all treatments.

The lime response obtained in pot culture experiments with white clover was not followed up in the field experiments as Greenleaf desmodium was known to be more tolerant of acid soils. Responses to lime by white clover and Greenleaf desmodium were 70% and 11%, respectively, in a pot culture experiment on a xanthozem soil from the Atherton Tableland (Kerridge *et al.* 1972).

Treatment details were:—

1. Fertilizer (kg ha^{-1}): KCl, 125 initial and yearly maintenance; $CaSO_4.2H_2O$, 240 initial, 120 yearly maintenance; $CuCO_3$, 7 initial; $ZnCO_3$, 7 initial; MoO_3, 0.36 initial; $CaH_4(PO_4)_2.H_2O$, 250 and 500 initial, 125 and 250 yearly maintenance at Dalrymple Heights, the higher rate as a basal treatment at Crediton.
2. Seeding rate (kg ha^{-1}): Greenleaf, 5; *Glycine,* 10; *Setaria,* 2.5.

Harvests were made for yield determinations after eight weeks regrowth in 1971 and ten weeks regrowth in 1972. Two 0.5 m^2 quadrats were cut from each plot at a height of 10 cm. The cut material was separated into grass, legume and broad leaf weeds, subsampled, and the subsamples oven dried at 70° C. Shoot samples of *Desmodium* collected in 1971 from all the treatments at Dalrymple Heights and the molybdenum treatments at Crediton were analysed by emission spectroscopy (Johnson and Simons 1972).

TABLE 2

Significant yield responses in pot culture experiments+

Location	Experiment 1 (Lime, P, Mo, K, S)	Experiment 2 (Lime, Mg, Cu, Zn, B, Co)
Bee Creek	S***, Lime**, Lime x Mo**	
East Funnel Creek	P***, Mo***, Lime***, Lime x Mo***	Lime**
Crediton	P***, Mo***, Lime***, Lime x Mo***, Lime x P**, Mo x P**	Lime**, Mg**, Lime x Cu** Mg x Co**, Cu x B**, Mg x B**, Lime x Mg**
Dalrymple Heights	P***, Mo***, K***, Lime***, Mo x P**, K x P**, K x Mo**, Mo x K x P**, Lime x K x S**	Lime**

+ **, *** – 1% and 0.1% level of significance, respectively.

RESULTS

Pot experiments

The dry matter yield responses are listed in Table 2. There were responses on all soils to molybdenum and lime, on three soils to phosphorus and on one soil to potassium and sulphur.

The phosphorus response for the four soils is shown in Figure 1. There were strong responses on the soils from Crediton and Dalrymple Heights, a moderate response on that from East Funnel Creek and none on that from Bee Creek. The lime x P interaction for the Crediton soil was due to the maximum yield being obtained at different phosphorus levels in the presence and absence of lime. The P x Mo and P x K interactions were due to greater response to molybdenum and potassium at the higher levels of applied phosphorus.

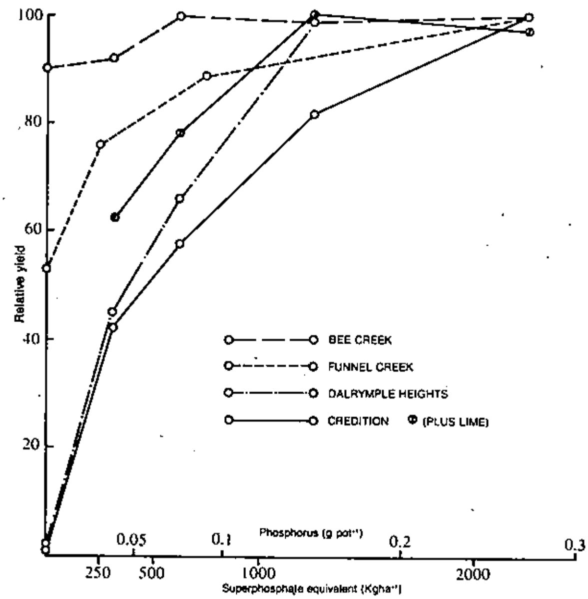

FIGURE 1

Response to phosphorus in pot culture experiments.

The magnitude of the lime response on the Crediton soil is shown in Figure 1. This was similar for the soil from Dalrymple Heights. In contrast, the Bee Creek and East Funnel Creek soils showed little response to lime other than that due to the release of molybdenum (Table 3).

Response to molybdenum followed the same pattern as that for phosphorus. Responses were very strong on the Crediton and Dalrymple Heights soils, moderate on the East Funnel Creek soil and slight on the Bee Creek soil (Table 3). Liming reduced the response to molybdenum on the East Funnel Creek, Bee Creek and Crediton soils resulting in the lime x Mo interaction. The additive effect of lime and molybdenum at Dalrymple Heights suggests an extremely low molybdenum content on this soil.

Sulphur only produced a yield increase on the Bee Creek soil (Table 3). However the chlorotic appearance of plants in the S_0Mo_1 treatments on the East Funnel Creek and Crediton soils and the dark green appearance and increase in nitrogen concentration of the S_1Mo_1 treatments (Table 3) indicated moderate and slight sulphur responses, respectively, for these two soils.

The potassium response was very strong on the Dalrymple Heights soil where the yield was increased from 3.0 to 6.4 g pot^{-1} in the absence of lime. The clover potassium concentrations in the presence and absence of potassium, with other nutrients non-limiting, were 1.2 and 0.8, 1.0 and 0.7, 1.7 and 1.2 and 0.8 and 0.4%, respectively,

TABLE 3

*Effect of molybdenum, sulphur and lime on dry matter yield (g pot^{-1}) and nitrogen concentration (%) of white clover.**

Location / Treatment	Bee Creek		East Funnel Creek		Crediton		Dalrymple Heights	
	Yield	%N	Yield	%N	Yield	%N	Yield	%N
$Lime_0\ S_0Mo_0$	4.6	2.2	3.6	2.6	0.8	2.1	0.4	1.4
$Lime_0\ S_1Mo_0$	5.3	3.1	2.5	2.4	0.8	2.3	0.4	1.7
$Lime_0\ S_0Mo_1$	5.0	2.3	7.2	2.6	6.3	2.9	6.5	3.2
$Lime_0\ S_1Mo_1$	6.5	3.6	8.2	3.7	7.0	3.4	6.4	3.3
$Lime_1\ S_0Mo_0$	5.6	2.6	8.0	2.8	8.8	3.0	2.0	2.0
$Lime_1\ S_1Mo_0$	6.6	3.4	9.2	3.6	8.6	2.9	1.8	1.7
$Lime_1\ S_0Mo_1$	5.2	2.7	8.3	2.7	11.0	3.5	8.3	3.3
$Lime_1\ S_1Mo_1$	6.8	3.6	8.9	3.7	11.0	3.6	9.0	3.5
L.S.D (P = 0.05)	0.5		1.2		0.9		1.0	

* Yield values are the mean of the treatments: $P_1 - P_4$, K_0 and K_1 for Bee Creek, P_3, P_4, K_0 and K_1 for East Funnel Creek and Crediton and P_3, P_4 and K_1 for Dalrymple Heights.
Nitrogen concentrations are for the P_4K_1 treatments.

for Bee Creek, East Funnel Creek, Crediton and Dalrymple Heights. Thus, though no yield responses occurred, the potassium concentrations in the 'minus' potassium treatments on the Bee Creek and East Funnel Creek soils fell below the critical concentration of 1.0% reported by Andrew and Robbins (1969). Potassium deficiency symptoms were present on the $K_0Mo_1S_1P_3$ and $K_0Mo_1S_1P_4$ treatments on the East Funnel Creek soil at harvest.

Magnesium carbonate increased the yield from 6.0 to 7.4 g pot^{-1} on the Crediton soil in the absence of lime but had no effect in the presence of lime. The Mg x Co interaction was due to a response to magnesium carbonate in the absence of cobalt. In the Mg x B interaction, response only occurred in the presence of both treatments.

On the Crediton soil copper increased the yield from 6.2 to 7.2 g pot^{-1} in the absence of lime but had no effect in the presence of lime. In the Cu x B interaction there was a response only in the presence of both nutrients.

On the Dalrymple Heights soil there was no response to potassium in the absence of molybdenum. Further, the response to both molybdenum and potassium was greater at the higher levels of phosphorus. The Ca x K x S interaction was associated with no response to sulphur at Ca_0K_0, a decrease in yield at Ca_0K_1 and Ca_1K_0, and an increase in yield at Ca_1K_1. However the magnitude of these effects was not greater than 0.5 g pot^{-1}.

Field experiments

(a) *Crediton*

There was good establishment of both legumes, Greenleaf desmodium and CPI 28279 glycine, and of Nandi setaria. In the first season there was a response to molybdenum in both colour and growth of the legumes. Growth of the *Desmodium* was much more vigorous than that of the *Glycine.*

Growth in the second summer was vigorous on the molybdenum fertilized *Desmodium* plots but relatively poor on all other treatments. Dry matter yields for a harvest made in February 1971 are shown in Table 4. There were significant main effect responses to molybdenum by both the grass and legumes though while the legumes, in particular *Desmodium,* responded similarly in both the presence and absence of sulphur, the greater response by *Setaria* was in the presence of sulphur. There was a significant Mo x S interaction for the grass with *Setaria* responding to sulphur only in the presence of molybdenum. There was no sulphur response in *Desmodium,* the leaf colour being dark green and nitrogen concentrations averaging 3.5% in both the presence and absence of sulphur where molybdenum had been added. The number of *Glycine* plants had decreased and the remaining plants were not vigorous at this harvest.

TABLE 4

Effect of molybdenum and sulphur on dry matter yield (kg ha^{-1}). Crediton

Species	Molybdenum (g ha^{-1}) 0		200		L.S.D.[+] (P = 0.05)
	Sulphur (Kg ha^{-1})		Sulphur (kg ha^{-1})		
	0	50 + 25*	0	50 + 25*	
			Harvest – 3.ii.71		
Desmodium	210	250	1,200	1,160	470
Setaria	330	220	290	840	430
Weed	170	230	100	290	
Total	710	700	1,590	2,290	780
Glycine	30	20	50	130	80
Setaria	330	110	300	500	430
Weed	130	200	120	190	
Total	490	330	470	820	780
			Harvest – 16.v.72		
Desmodium	70	30	710	830	270
Setaria	170	160	850	1,050	1, 030
Weed	620	850	640	830	
Total	860	1, 040	2,100	2,710	1,170

* 50 kg ha^{-1} S initial, 25 kg ha^{-1} S maintenance
\+ L.S.D. values shown are for the 3-way table, i.e. Species x Mo x S, where n = 4.

Severe weevil (*Leptopius* sp.) damage was observed on the *Desmodium* taproots in October 1971. The plots were dusted with dieldrin to control the infestation but regrowth was slow in the summer of 1971/72. Dry matter yields for 1972 are shown in Table 4. Yields of *Desmodium* and *Setaria* were very low in the absence of molybdenum and there was no response to applied sulphur. No harvests were made on the *Glycine* plots because of complete failure of the legume. There were no significant responses to potassium, copper or zinc in either 1971 or 1972.

(b) *Dalrymple Heights*

Establishment *of Desmodium* was uniformly good but approximately half of the plants at the lower rate of phosphorus were chlorotic and were not nodulated. There was complete nodulation and more vigorous growth at the higher rate of phosphorus application. *Glycine* established poorly and there were no differences between treatments. *Setaria* established well but made little growth. Mat grass re-established over most of the experiment.

Growth in the second summer was vigorous on all *Desmodium* treatments but too poor on the *Glycine* treatments to detect meaningful nutrient responses. Dry matter yields for a harvest in February 1971 are shown in Table 5. There were significant main effect responses to the higher rate of phosphorus and also to potassium by both *Desmodium* and *Setaria.* The main response by *Setaria* was to potassium and by *Desmodium* to potassium at the higher phosphorus application. The mean yield of *Setaria* with *Desmodium,* 1380 kg ha^{-1}, was significantly greater ($P = 0.05$) than with *Glycine,* 1160 kg ha^{-1}. Weed growth, which was dominantly mat grass, was suppressed where the addition of potassium resulted in more vigorous *Setaria* growth.

TABLE 5

Effect of phosphorus and potassium on dry matter yield (kg ha^{-1}), Dalrymple Heights

Species	Phosphorus (Initial + Maintenance – kg ha^{-1}) 62 + 31, Potassium (kg ha^{-1} yr^{-1}) 0	62 + 31, 62	124 + 62, Potassium (kg ha^{-1} yr^{-1}) 0	124 + 62, 62	L.S.D.* (P = 0.05)
	Harvest – 3.ii.71				
Desmodium	540	700	780	1,460	340
Setaria	990	1,640	1,070	1,810	350
Weed	130	10	110	10	
Total	1,660	2,350	1,960	3,280	460
Glycine	0	3	2	20	15
Setaria	710	1,310	1,210	1,390	350
Weed	160	70	130	110	
Total	870	1,383	1,342	1,520	460
	Harvest – 13.iv.72				
Desmodium	1,030	2,470	920	2,750	940
Setaria	700	1,690	1,120	2,100	570
Total	1,730	4,160	2,040	4,850	1,390

* L.S.D. values shown are for the 3-way table, i.e. Species x Mo x S, where n = 4.

Dry matter yields for the *Desmodium* treatments in April 1972 are shown in Table 5. The response to potassium was greater than in the previous year, but there was little response to the higher rate of phosphorus. The latter was only significant as a main effect response for *Setaria.* No *Glycine* survived and growth in these treatments was negligible.

(c) *Plant analysis*

The effect of the nutrient treatments on elemental concentration of *Desmodium* at Dalrymple Heights was examined by statistical analysis. Fertilization with phosphorus, potassium and zinc compounds increased the plant concentration of these elements but had no effect on the concentration of other elements. The sulphur and copper treatments had no effect on the concentration of these elements. The Crediton samples from the eight *Desmodium* treatments with added molybdenum were insufficient to allow statistical analysis but there appeared to be no effect of any nutrient treatments on elemental concentration. The chemical analyses are summarised in Table 6.

TABLE 6

*Mean chemical analyses of Desmodium, 1971 harvest**

N	P	S (%)	Ca	Mg	K	Cu	Zn (ppm)
			Crediton				
3.5	0.27	0.19	0.85	0.16	2.2	6	38
			Dalrymple Heights				
3.3	0.24 0.28	0.21	1.22	0.20	0.84 1.34	16	38 48

*Crediton : Means of the 8 Treatments with added molybdenum.

Dalrymple Heights : Means of 16 (for N, S, Ca, Mg, Cu) and 8 (for P, K, Zn) treatments. For P, K, and Zn, values are for treatments with the omission or addition of the respective nutrients.

DISCUSSION

These experiments have demonstrated a general requirement for molybdenum, a more localized requirement for potassium and confirmed the known requirement for phosphorus. Field experiments at Crediton and Dalrymple Heights confirmed the results of pot experiments for responses to phosphorus, molybdenum and potassium. The relative response to phosphorus on the four soils (Figure 1) was in accord with the available soil phosphorus values (Table 1). Also the response to potassium at Dalrymple Heights was in accord with the low exchangeable potassium value, 0.20 me/100 g, of that soil (Table 1).

The effect of sulphur in increasing the nitrogen concentration of clover on the Crediton soil suggested there might be a field response. There was an initial yield response by the grass to sulphur in the presence of molybdenum in 1971 but this was not accompanied by a response in yield or nitrogen concentration in the legumes and was not significant in 1972. In September 1972, soil samples were taken at 0-10, 10-20 and 20-40 cm depths from the minus and plus sulphur treatments and analysed for phosphate extractable sulphur. The values obtained were 12, 18 and 35 ppm S and 14, 22 and 44 ppm S, respectively, for the three depths and two treatments. Fox, Olson and Rhoades (1964) have suggested 10 ppm S, as a 'critical value' for lucerne. Thus the 'available' sulphur values explain the lack of any persistent field response when there was a response in the pot experiment conducted on surface soil.

The yield response by clover to copper in the absence of liming on the Crediton soil did not occur with *Desmodium* in the field. Moreover, the copper concentrations of 6 ppm in the *Desmodium* field samples indicate adequate copper for plant growth (Andrew and Thorne 1962). Copper deficiency was not found on xanthozem soils developed on granite on the Atherton Tableland (Kerridge *et al.* 1972) though it was found on adjacent coastal soils (Teitzel and Bruce 1971).

The pot response obtained to magnesium carbonate was not checked in the field but the plant magnesium concentration of 0.16%, while low, is above the level expected for response (C.S. Andrew personal communication). The quantity of magnesium carbonate added in the pot experiments was insufficient to change the overall pH but may have done so in the surface where it was applied, thus making conditions more favourable for nodulation. It is likely the effect of magnesium carbonate was on nodulation as there was no response in the presence of lime. A similar response by clover to magnesium carbonate occurred on a xanthozem developed on granite on the Atherton Tableland (Kerridge *et al.* 1972). The reason for the statistically significant interactions of cobalt and boron with magnesium are not understood. However as there was no main effect response to cobalt or boron it is unlikely that they are of real significance.

The main effect of the higher rate of phosphorus fertilization at Dalrymple Heights appears to have been on nodulation and establishment. Although there were greater responses in the first and second years at the higher rate there was little difference in yield between the two rates in the third year. Further, the phosphorus concentration of 0.24% P at the lower rate in the second year was above the critical value for *D. intortum* (Andrew and Robins 1969a). The single superphosphate equivalents for the lower rate are 526 kg ha^{-1} for establishment and 312 kg ha^{-1} for maintenance.

The lime response obtained in pot culture experiments with white clover could have been investigated under field conditions. However for Greenleaf desmodium, though there was a response of 11% to liming in a pot culture experiment on a xanthozem from the Atherton Tableland (Kerridge *et al.* 1972), there was no response to liming in the field (Kerridge unpublished data). *G. wightii* cv. Tinaroo did respond to liming in this field experiment but the growth was much poorer than that of *Desmodium*. The Ca x P interaction with white clover (Figure 1) does suggest that liming increased the availability of applied phosphorus as the maximum yield was obtained at a lower level of phosphorus in the presence than in the absence of the lime treatment.

The experiments were designed to define nutrient deficiencies rather than to determine the amounts required but the results do supplement existing establishment recommendations (these are for 500 kg ha^{-1} single superphosphate, containing 100 g molybdenum, in all areas except Bee Creek, for which 250 kg ha^{-1} is recommended). Our results suggest that on the xanthozems (Crediton and Dalrymple Heights) a slightly higher rate of phosphorus fertilization could be recommended and the phosphorus fertilizers can be chosen without regard to their sulphur content. Potassium is required in the higher rainfall Dalrymple Heights area. Results of a separate field experiment at Dalrymple Heights (P.C. Kerridge, unpublished data) have shown that 100 g molybdenum ha^{-1} was adequate for at least three years. At East Funnel Creek, 500 kg ha^{-1} molybdenised single superphosphate appears an adequate recommendation particularly with respect to molybdenum and sulphur. At Bee Creek, only sulphur and molybdenum appear necessary for the soils developed on basic intrusive rocks. Sulphur deficiency should be investigated in the field in these latter areas.

Greenleaf desmodium proved to be a productive legume where nutrient deficiencies were corrected and the higher yield of *Setaria* in the *Desmodium* than in the *Glycine* treatments at Dalrymple Heights in 1971 suggested the grass was responding to nitrogen fixed by the legume. *G. wightii* CPI 28279 has grown well in the Bee Creek area and on less acid and more recently cleared soils in the Crediton area (M.L. Everett, unpublished data). However it did not establish well or persist on the acid soils at Crediton or at Dalrymple Heights and cannot be considered an alternative legume, at least in the absence of liming, on these soils. Therefore an acceptable method of weevil control or an alternative species to Greenleaf desmodium should be sought because of its susceptibility to weevil attack.

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REFERENCES

ALLEN, A. (1965) — Dairying in the Australian tropics. A study of problems and trends in the Mackay district. *Australian Geographical Studies* **3**: 17-28.

ANDREW, C.S., and ROBINS, M.F. (1969a) — The effect of phosphorus on the growth and chemical composition of some tropical legumes. 1. Growth and critical percentages of phosphorus. *Australian Journal of Agricultural Research.* **20**: 665-674.

ANDREW, C.S. and ROBINS, M.F. (1969b) — The effect of potassium on the growth and chemical composition of some tropical and temperate pasture legumes. 1. Growth and critical percentages of potassium. *Australian Journal of Agricultural Research.* **20**: 999-1007.

ANDREW, C.S., and THORNE, P.M. (1962) — Comparative responses to copper of some tropical and temperate pasture legumes. *Australian Journal of Agricultural Research.* **13**: 821-835.

FOX, R.L., OLSON, R.A., and RHOADES, H.F. (1964) — Evaluating the sulphur status of soils by plant and soil tests. *Soil Science Society of America, Proceedings.* **28**: 243-246.

GOODCHILD, N.E. (1960) — Beat mat grass with pasture renovation. *Queensland Agricultural Journal* **86**: 529-530.

ISBELL, R.F., THOMPSON, C.H., HUBBLE, G.D., BECKMANN, G.G., and PATON, T.R. (1967) — Explanatory data for Sheet 4, Brisbane-Charleville-Rockhampton-Clermont Area. Atlas of Australian Soils, C.S.I.R.O. Australia.

JENSEN, A.R. (1946) — Mackay, Queensland, 1:250,000 Geological Series. Explanatory notes. Bureau of Mineral Resources, Geology and Geophysics Australia Sheet SF/55-8.

JOHNSON, A.D., and SIMONS, J.G. (1972) — Direct reading emission spectroscopic analysis of plant tissue using a briquetting technique. *Communications in Soil Science and Plant Analysis.* **3**: 1-9.

KERRIDGE, P.C., ANDREW, C.S., MURTHA, G.G. (1972) — Plant nutrient status of soils of the Atherton Tableland, North Queensland. *Australian Journal of Experimental Agriculture and Animal Husbandry.* **12**: 618-627.

TEITZEL, J.K., and BRUCE, R.C. (1971) — Fertility studies of pasture soils in the wet tropical coast of Queensland. 2. Granite Soils. *Australian Journal of Experimental Agriculture and Animal Husbandry.* **11**: 77-84.

WILLIAMS, C.H. and TWINE, J.R. (1967) — Determination of nitrogen, sulphur, phosphorus, potassium, sodium, calcium and magnesium in plant material by automatic analysis. C.S.I.R.O. Division of Plant Industry Technical Paper No. 24.

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