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PLANT NUTRIENT STATUS OF SOILS OF THE MAYVALE LAND SYSTEM, NORTH QUEENSLAND

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SUMMARY

Nutrient pot experiments were conducted on soils from sites in the Normanton-Croydon area of the Gulf of Carpentaria. The soils were representative of the major soils of the Mayvale Land System. Results indicate that the soils may be deficient in phosphorus, sulphur, potassium, lime and zinc.

I. INTRODUCTION

The major soils of the Mayvale Land System (Perry *et al.* 1964) in the Normanton-Croydon area of the Gulf of Carpentaria, have been mapped and described previously (Sleeman 1964, Isbell, Webb and Murtha 1968; Webb, Beeston and Hall 1974). The climate, geology, geomorphology and vegetation of the area have been described by Perry *et al.* (1964) and Webb, Beeston and Hall (1974). Webb, Beeston and Hall (1974) recognized four major soil associations and described the dominant soils. They presented chemical data indicating that the soils are of low fertility. In this paper, the results of glass-house studies on the nutrient status of soils from nine sites are presented.

II. MATERIALS AND METHODS

Bulk soil samples (0 to 10 cm) were selected from nine sites in July 1972. The soils selected for study were the dominant soils from Timora, Blackbull and Gum Creek soil associations (Webb, Beeston and Hall 1974), and each had a loamy sand A horizon. The samples were sieved through a 10 mm mesh. The soil was air-dried, and 450 g put into each of a series of aluminium pots (13 cm high x 6·5 cm diameter) lined with polyethylene bags. To achieve similar bulk density in each pot, the soil was lightly tamped at regular intervals. A sample of each soil was analysed for a number of attributes (table 1).

Two series of experiments were conducted—

1. A phosphorus rate experiment (5 rates of P x 4 replications (table 2)) on four soils, with basal addition of nutrients used in the concurrent factorial experiment.
2. A quarter replicate of a 2^8 factorial nutrient experiment on nine soils.

For the factorial experiments, treatments were the presence or absence of sulphur, lime, potassium, copper, zinc, molybdenum, magnesium and boron combined, and manganese and iron combined. Details of rates and chemical forms of nutrients are given in table 3. A basal phosphorus application was made to all pots and Townsville stylo (*Stylosanthes humilis*) was used as the test plant.

For each experiment, sufficient seeds were planted to achieve a sward of 6 to 10 plants per pot. Pots were watered to field capacity two to three times a day with deionized water. Plant tops were harvested 53 days after planting then dried at 70°C and weighed. Dried plant material for selected treatments was ground in a 'Glen Creston' stainless steel mill.

Following Kjeldahl digestion of the plant samples, nitrogen and phosphorus were determined by AutoAnalyser, potassium by flame photometry and calcium and magnesium by atomic absorption spectrophotometry. Sodium was determined by flame photometry after extraction with ammonium oxalate. Total sulphur, copper, zinc, and managanese were determined by X-ray fluorescence.

Analytical methods to determine soil pH, chloride, nitrogen, organic carbon, exchangeable cations, exchange capacity, available phosphorus and particle size distribution have been described previously (Webb, Beeston and Hall 1974). Copper and zinc were determined by atomic absorption spectrophotometry after extration with DTPA (Follett and Lindsay 1971), while total phosphorus and sulphur were determined by X-ray fluorescence. Extractable sulphur was determined using the method of Johnson and Nishita (1952) after extraction with calcium phosphate for 1 hour (Barrow 1967).

III. RESULTS

(a) Soil analyses. Analytical data for the soils are presented in table 1.

All soils were acid. They had extremely low levels of phosphorus and an overall deficiency was indicated. Sulphate-sulphur and total sulphur levels of the surface soils were extremely low. Exchangeable cation values were all extremely low, exchangeable potassium being below the suggested threshold value of 0·2 m. equiv./100 g (Williams and Lipsett 1968, Piper and de Vries 1960, Kerr and Von Stieglitz 1938).

TABLE 2

Rates of $NaH_2PO_4.2H_2O$ Used in Phosphorus Rate Experiments

P rate kg ha^{-1}	$NaH_2PO_4.2H_2O$ g pot^{-1}
0	0
20	0·033
60	0·099
120	0·198
240	0·396

TABLE 1

ANALYTICAL DATA FOR SURFACE SOILS (0–10 cm) USED IN GLASSHOUSE EXPERIMENTS

Determination	Sites								
	101	108	115	150	229	231	262	265	275
Principal profile form	Gn 2·94	Dy 3·42	Gn 2·21	Dy 3·42	Dy 3·42	Gn 2·94	Dy 3·42	Dy 3·82	Gn 2·94
pH	5·7	5·9	5·9	5·6	6·0	5·5	5·9	5·5	5·6
Nitrogen (%)	0·020	0·022	0·017	0·020	0·020	0·017	0·022	0·011	0·022
Organic carbon (%)	0·10	0·19	<0·05	<0·05	0·10	0·28	0·46	0·46	0·46
Sulphate-sulphur (p.p.m.)	0·5	2·0	3·0	2·0	0·5	<0·5	1·5	1·2	1·5
Total sulphur (p.p.m.)	30	50	30	30	50	40	50	30	30
C:N ratio	5	9			5	16	21	42	21
Exchangeable cations (m.equiv./100 g)									
Calcium	0·4	2·0	1·6	1·2	1·6	1·0	1·6	1·2	0·8
Magnesium	0·4	0·4	0·4	0·4	0·4	0·4	0·4	0·2	0·2
Sodium	<·05	<·05	<·05	<·05	<·05	<·05	<·05	<·05	<·05
Potassium	0·25	0·10	0·25	<·05	<·05	<·05	0·25	<·05	<·05
Exchange capacity (m.equiv./100 g)	1·6	3·2	2·6	2·6	1·8	1·0	1·0	1·4	1·2
Total phosphorus (p.p.m.)	70	110	70	100	120	70	110	70	70
Available phosphorus (p.p.m.)	4	4	2	2	2	2	2	2	4
Copper (p.p.m.)	0·3	0·3	0·2	0·4	0·2	0·1	0·1	0·3	0·2
Zinc (p.p.m.)	0·3	0·4	0·2	0·4	0·3	0·1	0·3	0·2	0·2
Clay (%)	4	6	6	6	11	6	11	8	8

TABLE 3

RATES AND CHEMICAL FORMS OF NUTRIENTS USED IN FACTORIAL EXPERIMENTS

Treatment	Compound	Rate of Application	
		g pot^{-1}	kg ha^{-1}
S	Na_2SO_4 (anhydrous)	0·0455	138
K	KCl	0·0427	127
Mg	$MgCl_26H_2O$	0·0299	91
Ca	$CaCO_3$	0·2096	635
Mo	$(NH_4)_6Mo_7O_{24}4H_2O$	0·0018	0·565
Zn	$ZnCl_2$	0·0052	15·88
Cu	$CuCl_22H_2O$	0·0052	15·88
Mn	$MnCl_2.4H_2O$	0·0029	9·1
B	$Na_2B_4O_7.10H_2O$	0·0011	3·4
Fe	Iron chelate	0·2% spray	

Basal nutrient .. 0·113 g pot^{-1} $NaH_2PO_4.2H_2O$
Pot size .. .. 13 cm high x 6·5 cm diameter

(b) NUTRIENT EXPERIMENTS. Yields for the phosphorus rate experiments are shown in table 4.

TABLE 4

MEAN YIELD OF *Stylosanthes humilis* GROWN IN POTS AT DIFFERENT PHOSPHORUS APPLICATION RATES

Treatment	Yield g pot^{-1}			
	Sites			
P kg ha^{-1}	108	231	265	275
0	0·13	0·11	0·05	0·03
20	0·89	0·76	0·54	0·61
60	1·29	0·82	0·51	0·79
120	1·30	0·64	0·45	0·66
240	0·73	0·38	0·19	0·31
Necessary differences for significance 5%	0·61	0·31	0·28	0·30
Necessary differences for significance 1%	0·84	0·43	0·39	0·42

On each soil type plant dry matter yields were significantly different according to phosphorus rate.

Yields within 90% of maximum yield were obtained from phosphorus rates between 20 and 60 kg P ha^{-1}. A depression in yield occurred at the highest phosphorus rates for all soils. Plant phosphorus concentrations for nil phosphate treatment on all soils ranged from 0·02 to 0·10% and were below the critical concentration of 0·17% P (Andrew and Robins 1969a). Plant phosphorus concentrations in the highest treatments exceeded 0·67% P. As phosphorus was applied as sodium dihydrogen phosphate, plant sodium concentration was also determined. Sodium concentration in plants from the 20 kg P ha^{-1} treatment ranged from 0·08 to 0·11% Na and in plants from the 240 kg P ha^{-1} treatment values were between 0·28 and 0·39% Na.

In the treatment range to 60 kg P ha^{-1}, plant phosphorus and nitrogen concentrations were highly correlated (r = ·87, P < 0·01) for all soils.

The significant main effects and interactions based on yield data of the factorial experiments are shown in table 5.

TABLE 5

RESULTS OF FACTORIAL EXPERIMENTS IN THE GLASSHOUSE ON NINE SOILS. MAIN EFFECTS AND INTERACTIONS FOUND IN THE FIRST HARVEST YIELD DATA

Effect	Sites								
	101	108	115	150	229	231	262	265	275
Mean yield g pot^{-1}	1·04	1·27	1·28	1·15	1·14	1·21	1·33	1·08	0·96
Ca	**	*						**	*
S	**	**	**	**	**	**	**	**	**
K						**	**	**	**
Zn		**				*	**	*	
Mo								*	
Cu								*	
Mg–B								*	
Interaction									
Ca x S	*								*
Ca x K	*					*		**	
S x K			*			**	**	**	**
S x Zn		**				**	**	**	
S x Cu								**	
S x Mg–B								**	
K x Zn					*				
K x Mo			*						
Mg–B x Cu	*								
Mg–B x Zn			*						
Mg–B x Mo					**				
Mg–B x Mn–Fe									*
Mo x Mn–Fe							*		

* Yields of treated plants significantly different from that of untreated plants at 5% level.
** Yields of treated plants significantly different from that of untreated plants at 1% level.

All of the soils were severely deficient in sulphur. Plant dry matter yield ratios of treated to untreated pots for sulphur main effect ranged between 2·6 and 5·9 for the soils studied. Positive yield responses to treatment with potassium, lime or zinc were recorded in at least five soils, either as main effects or as interactions with other nutrients. Plants in three soils responded to molybdenum and in one soil to copper.

Responses to other nutrients as main effects did not occur unless sulphur was present except in soils 108 and 265 where lime treatment alone caused a response. Plant sulphur concentrations of the nil-sulphur treatments for all soils were 0·07 to 0·08% which was below the critical concentration of 0·10% S considered by Jones and Robinson (1970) to indicate sufficiency. Values for sulphur treatments were 0·21 to 0·23% S.

Lime x potassium interactions occurred on soils 101, 231 and 265. Plant yield responses resulted from lime treatment only in the presence of potassium. Similarly on soils 115 and 229 molybdenum and zinc respectively increased plant yield only in the presence of potassium. Zinc also increased yield in the absence of the magnesium, boron treatment on soil 115. Magnesium, boron treatment interacted with copper (soil 101), molybdenum (229) and manganese, iron (275) to cause plant yield depressions. In the molybdenum x manganese, iron interaction on soil 262, molybdenum increased plant yield in the absence of the manganese, iron treatment.

After correction for sulphur deficiency, plant zinc concentrations in nil-zinc treatments on responsive soils were 12 to 16 p.p.m. and for zinc treatments 86 to 100 p.p.m. On soil 275, where no zinc response was recorded, mean plant zinc concentration in the nil-zinc treatment was 35 p.p.m.

In the presence of sulphur, mean plant potassium concentrations in nil-potassium treatments for soils which responded to potassium were 0·67 to 0·75%, while those in potassium treatments were 1·2 to 1·5%. The potassium concentrations for the nil-potassium treatments were slightly higher than the suggested critical concentration of 0·6%K (Andrew and Robins 1969).

Mean plant copper concentration in nil-copper treatments in soil 265 was 4·7 p.p.m. while that in copper treatments was 8·5 p.p.m. Copper concentrations in plants from nil-copper treatments on non-responsive soils were 4·9 to 5·7 p.p.m.

IV. DISCUSSION

The nine soils used in the glasshouse experiments were typical, morphologically and chemically, of the major soils described previously (Webb, Beeston and Hall 1974). The total nitrogen and organic carbon values for the soils were extremely low and the C:N ratios were generally very wide. The nitrogen mineralization of the soils would be very low.

The experimental results indicate that phosphorus and sulphur are the main nutrients limiting the growth of *Stylosanthes humilis* on these soils. Levels of available phosphorus and sulphur in the soils were so low that the plant responses obtained were expected. The depressions in plant yield for the high phosphate rates were probably a result of excessive sodium concentrations in the plants due to the use of sodium phosphate. Phosphorus concentrations were not excessive. The marked difference in mean plant yields for the four soils used in the phosphorus rate experiment (table 4) are difficult to explain. The pots were rotated weekly in the glasshouse so positional effects would not account for the differences. Chemically and physically there is very litle difference between the four soils. Exchangeable potassium values of all soils were extremely low and it was expected that more of the soils would have responded to potassium treatment.

The interactions with sulphur of potassium, lime and zinc (with the exceptions noted earlier) indicate that sulphur deficiency was over-riding all other deficiencies. The lime x potassium, lime x zinc and lime x molybdenum interactions are difficult to explain. The various interactions of the magnesium-boron treatment indicate that it is likely to mask response to zinc. Similarly manganese, iron treatment may prevent response to molybdenum on soil 202.

The responses to lime are not explained. Calcium concentration in plants from the nil-lime treatments were satisfactory (1·66 to 1·69% Ca) and nitrogen concentrations were not affected (mean 3·52% N). Plant sulphur concentrations also were not affected, so stimulated sulphur mineralization appears unlikely. The responses to lime are unlikely to be due to soil pH effects since *S. humilis* is tolerant of soils with low pH (Humphreys 1967).

Andrew and Thorne (1962) regarded 4 to 5 p.p.m. copper concentration as marginal in legumes, and greater than 5 p.p.m. sufficient. The responsive soils are in agreement with these ratings. DTPA extractable copper level in soil 265 was low and similar to the copper levels for the other eight soils. The soil and plant data together indicate that copper levels in the soils are marginal and deficiencies may occur.

The soil zinc values were low and probably in the deficiency range. Positive responses to zinc on six of the soils gives added support to this hypothesis.

Jones (1973) reported on multiple deficiencies of phosphorus, sulphur, zinc, copper and potassium on deep sandy soils of Cape York Peninsula. The sandy soils included in this current study are situated in a similar climatic zone and it is of interest that a similar range of nutrient deficiencies may exist.

V. CONCLUSIONS

The glasshouse nutrient assessment of the major soils in the Mayvale Land System indicates that the soils are extremely infertile and are likely to respond to phosphorus, sulphur, potassium, lime, zinc and possibly molybdenum. Copper deficiencies may occur.

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