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STUDIES ON MAJOR SOILS OF THE FORSAYTH GRANITE

2. GLASSHOUSE NUTRIENT ASSESSMENT

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SUMMARY

The nutrient status of a catenary sequence of four soils developed on Forsayth Granite in the Georgetown area of north Queensland was studied in a glasshouse experiment. Townsville stylo (*Stylosanthes humilis*) was used as the test legume and dry matter yield and chemical analytical data are presented. Major responses resulted from phosphorus and sulphur applications. There was little response to lime or trace element treatments although plant analytical data provide some evidence of nutrient interactions.

I. INTRODUCTION

Morphological and chemical properties of the major soils developed on Forsayth Granite were described in part 1 (Webb 1975). Pastures on these soils are of poor quality and yields are low (Perry and Lazarides 1964).

Glasshouse studies were undertaken in an attempt to define possible soil nutrient deficiencies. In this paper results of the studies on four soils are presented.

II. MATERIALS AND METHODS

Surface soil (0 to 15 cm) was collected from four sites. The soil from each site was sieved and thoroughly mixed. For each soil, a phosphorus rate experiment and a half replicate of a 2^6 factorial nutrient experiment were carried out in pots in the glasshouse. The 15 cm diameter polystyrene pots were lined with polythene. To each, 1 800 g of air-dry soil was added. Twice a day, all pots were watered with deionized water to field capacity. Pots were repositioned randomly each week. Townsville stylo (*Stylosanthes humilis*) was used as the indicator plant.

The phosphorus rate experiments comprised five levels of phosphorus replicated three times. Rates were calculated to be equivalent to 0, 10, 30, 60, 120 kg P ha^{-1}. A basal application of all nutrients used in the factorial experiments was applied.

In the factorial experiments, a basal dressing of phosphorus was applied to all pots at the rate of 0.41 g of $NaH_2PO_4.2H_20$ per pot (approximately 50 kg P ha^{-1}). The nutrients used in the factorial experiment were sulphur, lime, molybdenum, copper, zinc, potassium, magnesium, manganese, boron and iron.

The last five were bulked as a miscellaneous treatment. Details of rates and forms of nutrients are given in table 1.

Plants were harvested at the preflowering stage, dried at 75°C and weighed. Plant material from the replicates of each phosphorus treatment in the phosphorus rate experiments was bulked to give sufficient sample for analysis. Phosphorus, sulphur, potassium, magnesium, calcium, manganese, copper and zinc concentrations of plants were determined on an X-ray fluorescence spectrograph. Nitrogen determinations were carried out using Kjeldahl digests and an AutoAnalyser. Methods of soil analyses were described by Webb (1975).

III. RESULTS

Soil analytical data for the four soils used in the pot experiments are shown table 2. Chloride levels were less than 0.001% and are not shown.

TABLE 1

RATES AND FORMS OF NUTRIENTS USED IN POT EXPERIMENTS

Treatment		Compound Applied	Rate of Application	
			kg ha^{-1}	g pot^{-1}
Mo		$(NH_4)_6Mo_7O_{24}\ 4H_2O$	0·56	0·00071
Ca		$CaCO_3$	1 255	1·59
S		Na_2SO_4 (anhydrous)	99	0·126
Cu		$CuCl_2\ 2H_2O$	7·8	0·00994
Zn		$ZnCl_2$	5·6	0·0071
Mn	Miscellaneous	$MnCl_2\ 4H_2O$	18	0·0227
Fe	Miscellaneous	Ferric monosodium salt of EDTA	0·2% solution	
K	Miscellaneous	$KHCO_3$	168	0·213
Mg	Miscellaneous	$MgCl_2.6H_2O$	90	0·114
B	Miscellaneous	$Na_2B_4O_7.10H_2O$	3·4	0·00426

(a) Phosphorus experiments

Yields and plant nutrient concentrations for the different phosphorus rates on each of the four soils are shown in table 3. Response was similar for each soil with yield increasing sharply to 30 kg P ha^{-1} and then levelling out. Plant phosphorus concentrations for the 0 and 10 kg P ha^{-1} application rate for each soil were below the critical concentration of 0.17% (Andrew and Robins 1969b).

Plant phosphorus increased linearly with phosphorus application rate for each soil. The regression equations for each soil were—

$$\begin{aligned} &\text{Uc4.11} : y = 0{\cdot}097 + 0{\cdot}0021x\ (P < {\cdot}01)\\ &\text{Uc5.23} : y = 0{\cdot}143 + 0{\cdot}0016x\ (P < {\cdot}01)\\ &\text{Dy3.21} : y = 0{\cdot}105 + 0{\cdot}0018x\ (P < {\cdot}01)\\ &\text{Dy3.43} : y = 0{\cdot}089 + 0{\cdot}0021x\ (P < {\cdot}01)\end{aligned}$$

y = plant phosphorus (%), x = phosphorus (kg ha^{-1}) applied

There were no significant differences between the slopes of the regression equations.

TABLE 2

ANALYTICAL DATA FOR THE FOUR SOILS (0–15 CM) USED IN POT EXPERIMENTS

Great Soil Group	Principal Profile Form	pH	Available Phosphorus (p.p.m.)	Exchangeable Cations (m—equiv/100 g)					Total N (%)	Org. C (%)
				Ca++	Mg++	Na+	K+	C.E.C.		
Lithosol-earthy sand intergrade	Uc 4·11	5·4	<5	0·8	0·3	<0·1	0·10	2	0·03	0·33
Earthy sand	Uc 5·23	5·8	<5	1·2	0·3	<0·1	0·16	3	0·02	0·24
Soloth	Dy 3·21	6·0	<5	1·3	0·5	0·2	0·10	3	0·02	0·18
Solodic	Dy 3·43	5·5	<5	0·7	0·4	<0·1	0·09	4	0·02	0·21

(b) Factorial experiments

Treatment main effects on plant yield for the four soils are shown in table 4.

(i) SULPHUR EFFECTS. A very marked increase in plant yield resulted from the application of sulphur on three of the soils. The increase on the Uc5.23 soil was not significant. However, on examination of a lime x sulphur x miscellaneous treatment interaction on the Uc5.23 soil, it was found that sulphur caused a significantly higher plant yield in the absence of lime and miscellaneous treatments. The improved sulphur nutrition caused a marked increase in plant nitrogen and plant sulphur concentration on all soils, in plant magnesium on three soils, and in plant potassium and phosphorus on two soils (table 5).

TABLE 3

YIELD AND NUTRIENT CONCENTRATIONS IN *Stylosanthes humilis* GROWN IN POTS AT DIFFERENT PHOSPHORUS LEVELS ON FOUR DIFFERENT SOILS

Soil P.P.F.	Treatment Phosphorus (equiv. kg/ha)	Mean O.D.* Yield (g pot^{-1})	P (%)	S (%)	K (%)	Mg (%)	Ca (%)	N (%)
Uc4.11	0	1·63	0·09	0·09	0·95	0·34	1·04	2·1
	10	3·80	0·11	0·22	0·25	0·31	0·87	2·4
	30	5·70	0·17	0·23	1·26	0·34	0·82	2·25
	60	6·61	0·24	0·20	1·16	0·33	0·79	2·55
	120	6·50	0·34	0·23	1·13	0·36	0·73	2·55
Necessary differences for significance 5%		1·05						
1%		1·52						
Uc5.23	0	1·02	0·14	0·25	1·33	0·34	1·10	2·25
	10	1·88	0·16	0·24	1·26	0·32	0·94	1·84
	30	3·48	0·18	0·25	1·53	0·30	0·88	2·50
	60	4·28	0·26	0·24	1·41	0·32	0·63	2·70
	120	5·76	0·33	0·23	0·81	0·35	0·77	2·60
Necessary differences for significance 5%		0·82						
1%		1·20						
Dy3.21	0	2·02	0·09	0·08	0·94	0·31	0·89	1·90
	10	3·86	0·12	0·21	1·44	0·30	0·75	1·75
	30	5·70	0·17	0·21	1·35	0·32	0·70	2·65
	60	7·00	0·23	0·20	1·30	0·32	0·65	2·60
	120	6·65	0·31	0·17	1·12	0·33	0·62	2·45
Necessary differences for significance 5%		1·72						
1%		2·50						
Dy3.43	0	1·65	0·09	0·19	1·27	0·33	1·14	1·50
	10	2·20	0·12	0·17	1·10	0·37	0·99	1·90
	30	3·40	0·14	0·18	1·11	0·31	0·90	1·80
	60	3·68	0·21	0·21	1·23	0·34	0·87	1·25
	120	4·50	0·34	0·23	1·14	0·34	0·87	1·80
Necessary differences for significance 5%		1·41						
1%		2·06						

* O.D. — oven dried

The sulphur concentration in plants which received no added sulphur was close to the suggested critical concentration of 0.10% S (Jones and Robinson 1970). Potassium concentration in plants (table 5) was well above the critical concentration of 0.6% K established by Andrew and Robins (1969c) while the phosphorus concentrations (table 5) were greater than the critical concentration of 0.17% P. This was to be expected since a basal phosphorus nutrient had been applied.

Sulphur featured in significant interactions (P<.05) with lime on the Uc4.11 and Dy3.21 soils, with the miscellaneous treatment on Uc4.11 soil, and with lime and miscellaneous treatment on the Uc5.23 soil. In the sulphur x lime interaction, a significant yield response resulted from sulphur only when lime was absent. Sulphur overcame the depressing effect of miscellaneous treatment on the Uc4.11 soil.

TABLE 4

MAIN EFFECTS OF TREATMENTS ON DRY MATTER YIELD OF *Stylosanthes humilis* GROWN ON FOUR DIFFERENT SOILS (g pot^{-1})

Treatment	Soil			
	Uc4·11	Uc5·23	Dy3·21	Dy3·43
Mo_0	5·88	5·23	5·63	4·72
Mo_1	6·20	5·44	5·65	4·10*
$lime_0$	5·89	5·50	5·62	4·58
$lime_1$	6·19	5·17	5·67	4·25
S_0	5·33	5·05	4·99	3·94
S_1	6·75**	5·62	6·29**	4·89**
Cu_0	5·88	5·42	5·47	4·30
Cu_1	6·20	5·25	5·82	4·52
Zn_0	5·94	5·30	5·62	4·35
Zn_1	6·13	5·38	5·66	4·48
$Miscellaneous_0$	6·33	6·03	5·70	4·89
$Miscellaneous_1$	5·75**	4·64**	5·88	3·94**
Standard error	0·18	0·21	0·08	0·19
Necessary differences for significance 5%	0·57	0·67	0·58	0·59
Necessary differences for significance 1%	0·81	0·96	0·82	0·84

* Differences in yield significant at 5% level.
** Differences in yield significant at 1% level.

(ii) LIME AND ZINC EFFECTS. Apart from the interaction with sulphur and miscellaneous treatments mentioned above and a lime x copper interaction on the Dy3.43 soil, lime had no significant effects on plant yield. In the significant lime x copper interaction (P<.05) lime depressed yield when copper was not applied.

Concentrations of phosphorus and manganese in the plants (table 6) were reduced significantly (P<.01). Plant zinc concentrations were determined only on plants from the Dy3.43 soil and lime had no significant effect on these.

Zinc did not improve plant yield on any soil. Plant zinc concentration of 43.8 p.p.m. in the zinc treatment was significantly higher (P<.01) than the value of 26.9 p.p.m. in the nil-zinc treatment. Zinc treatment decreased plant phosphorus concentrations significantly on three soils (table 7).

(iii) MOLYBDENUM AND COPPER. No plant responses were obtained from molybdenum or copper application on any of the soils. Copper concentration was determined only on plants grown on the Dy3.43 soil. There was a significant increase in concentration from 3.3 p.p.m. for nil-copper treatments to 4.5 p.p.m. Cu for copper treatments (P<.01).

(iv) MISCELLANEOUS TREATMENT EFFECTS. This treatment caused a yield reduction on the Uc4.11, the Uc5.23 and the Dy3.43 soils (table 3).

TABLE 5

THE EFFECT OF SULPHUR TREATMENT (Na_2SO_4) ON NITROGEN, SULPHUR, MAGNESIUM, POTASSIUM AND PHOSPHORUS CONCENTRATION IN *Stylosanthes humilis* GROWN ON FOUR SOILS

Soil	Treatment	Chemical Composition				
		N (%)	S (%)	Mg[1] (%)	K[2] (%)	P[3] (%)
Uc4·11	S_0	1·79	0·09	0·32	0·91	0·25
	S_1	2·55**	0·25**	0·39*	1·14**	0·30**
Necessary difference for significance 5%		·243	·008	·065	·086	·018
1%		·346	·011	·092	·122	·026
Uc5·23	S_0	2·05	0·11	0·32	1·14	0·31
	S_1	2·68**	0·28**	0·38**	1·29*	0·34
Necessary difference for significance 5%		·172	·023	·026	·114	·042
1%		·245	·033	·038	·162	·060
Dy3·21	S_0	1·90	0·08	0·27	0·95	0·24
	S_1	2·85**	0·24**	0·35*	1·15	0·29**
Necessary differences for significance 5%		·203	·013	·071	·204	·019
1%		·289	·018	·103	·290	·027
Dy3·43	S_0	1·72	0·10	0·33	1·06	0·25
	S_1	2·20**	0·24**	0·38	1·12	0·27
Necessary differences for significance 5%		·160	·011	·059	·197	·021
1%		·228	·016	·084	·281	·029

* Differences in nutrient concentration significant at 5% level.
** Differences in nutrient concentration significant at 1% level.
[1] Values are means for treatments not receiving Mg
[2] Values are means for treatments not receiving K
[3] Values are means for treatments receiving P

IV. DISCUSSION

In the nutrient studies reported here, only the 0 to 15 cm zone of the soils has been considered. For pasture soils under a seasonal environment where annual species are important, this zone could be expected to have a major influence on plant growth.

Plant response data from the pot experiments indicate that phosphorus and sulphur are the main nutrients limiting plant growth. The possibility of a molybdenum deficiency cannot be disregarded. The soils are acid and responses to molybdenum have been noted in other areas under similar conditions (Anderson 1942, Andrew 1968).

Excessively high soil temperatures could account for the lack of response to molybdenum. Temperatures 5 cm below the soil surface in pots reached 42°C in another experiment being conducted at the same time (Crack, personal communication). Norris (personal communication) suggested that at temperatures greater than 40°C nodules of legumes are ineffective.

TABLE 6

THE EFFECT OF LIME APPLICATION ON PLANT Mn, P AND Zn CONCENTRATIONS*

Soil	Treatment	Chemical Composition		
		Mn[1] (p.p.m.)	P[2] (%)	Zn[3] (p.p.m.)
Uc4·11	$lime_0$ ..	253	0·29	N.A.
	$lime_1$ ..	43**	0·26**	N.A.
Necessary differences for significance 5%		54·7	·018	
1%		77·9	·026	
Uc5·23	$lime_0$ ..	228	0·36	N.A.
	$lime_1$ ..	45**	0·29**	N.A.
Necessary differences for significance 5%		13·7	·042	
1%		19·5	·060	
Dy3·21	$lime_0$ ..	N.A.	0·29	N.A.
	$lime_1$ ..	N.A.	0·24**	N.A.
Necessary differences for significance 5%			·019	
1%			·027	
Dy3·43	$lime_0$ ..	182	0·29	31·3
	$lime_1$ ..	40**	0·23**	22·6
Necessary differences for significance 5%		21·7	·021	9·16
1%		30·9	·029	13·02

* Differences in nutrient concentration significant at 5% level
** Differences in nutrient concentration significant at 1% level
N.A.—no analyses done
[1] Values are means for treatments not receiving Mn
[2] Values are means for treatments receiving P
[3] Values are means for treatments not receiving Zn

TABLE 7

EFFECT OF ZINC ON PHOSPHORUS CONCENTRATION IN *Stylosanthes humilis* GROWN ON FOUR DIFFERENT SOILS IN POTS

—	Phosphorus Concentration (%)			
	Uc4·11	Uc5·23	Dy3·21	Dy3·43
Zn_0	0·29	0·33	0·28	0·27
Zn_1	0·27*	0·32	0·25**	0·25**
Necessary differences for significance 5%	0·02	0·04	0·02	0·02
1%	0·03	0·06	0·03	0·03

* Differences in phosphorus concentration significant at 5% level
** Differences in phosphate concentration significant at 1% level

Plant analytical data suggest that zinc and copper concentrations of plants on the untreated Dy3·43 soil may be approaching levels where a plant growth response could be expected. Jones (1973) obtained significant yield increases in Townsville stylo growth from the application of zinc where plant zinc rose from 19·6 to 43·3 p.p.m. The similar rise in plant zinc concentrations resulting from zinc application in this experiment tends to indicate that for the Dy3·43 soil, zinc may have been marginal.

The plant analytical data (table 7) provide some evidence of zinc x phosphorus antagonism such as reported by other workers (Martin *et al.* 1965; and Ellis *et al.* 1964) although in this experiment no yield effects were evident. Phosphorus had been applied as a basal fertilizer and, although there was slight reduction in plant phosphorus when zinc was applied, all plant phosphorus concentrations were well above the critical concentration.

Andrew and Thorne (1962) suggested that, for legumes, a copper concentration of 4 to 5 p.p.m. is marginal, and less than 4 indicates deficiency. Using these criteria, copper concentrations of plants grown on the Dy3·43 soil were marginal or in the deficient range.

The lime x copper interaction for yield on Dy3·43 soil is difficult to explain. The interaction appeared to be due to copper being made less available by lime, but plant analytical data do not support this. Lime reduced the plant copper concentration from 3·4 to 3·0 p.p.m. (non-significant statistically). Those values are in the deficiency range (Andrew and Thorne 1962).

The reduction in plant yield on the three soils caused by the miscellaneous treatment does not appear to be due to a nutrient toxicity or cation imbalance. Plant analyses did not suggest chloride or manganese toxicity and calcium, magnesium, phosphorus, copper and zinc concentrations were not affected. Soil pH changes because of the $KHCO_3$ in the treatment may have occurred resulting in an induced deficiency, but plant analyses did not resolve the problem. Although no plant response to potassium application was demonstrated, soil analytical data indicate that exchangeable potassium values in the soils are very low.

Field experiments are required to test the sufficiency of phosphorus, sulphur, molybdenum, potassium, copper and zinc. Soil phosphorus levels are so low that in field experiments it would be desirable to apply a substantial basal phosphorus application to assess the other nutrients. Separate phosphorus rate experiments would be required.

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REFERENCES

ANDERSON, A. J. (1942).—Molybdenum deficiency on a South Australian ironstone soil. *J. Aust. Inst. agric. Sci.* 8:73-5.

ANDREW, C. S. (1968).—Problems in the use of chemical analyses for diagnosis of plant nutrient deficiencies. *J. Aust. Inst. agric. Sci.* 34:154-62.

ANDREW, C. S., and ROBINS, M. F. (1969a).—The effect of phosphorus on the growth and chemical composition of some tropical pasture legumes. II. Nitrogen, calcium, magnesium, potassium and sodium contents. *Aust. J. agric. Res.* 20:675-85.

ANDREW, C. S., and ROBINS, M. F. (1969b).—The effect of phosphorus on the growth and chemical composition of some tropical pasture legumes. 1. Growth and critical percentage of phosphorus. *Aust. J. agric. Res.* 20:665-74.

ANDREW, C. S., and ROBINS, M. F. (1969c).—The effect of potassium on the growth and chemical composition of some tropical and temperate pasture legumes. I. Growth and critical percentages of potassium. *Aust. J. agric. Res.* 20:999-1007.

ANDREW, C. S., and THORNE, PEGGY M. (1962).—Comparative responses to copper of some tropical and temperate pasture legumes. *Aust. J. agric. Res.* 13:821-35.

ELLIS, R. Jr., DAVIS, J. F., and THURLOW, D. L. (1964).—Zinc availability in calcareous Michigan soils as influenced by phosphorus level and temperature. *Proc. Soil Sci. Soc. Am.* 28:83-6.

GRAHAM, T. G. (1964).—Results of fertilizer trials in the Rockhampton district. *Proc. cent. Qd Agros. Conf., Biloela, Qd* 1964. Sect. 12b.

HUMPHREYS, L. R. (1967).—Townsville lucerne: History and prospect. *J. Aust. Inst. agric. Sci.* 33:3-13.

JONES, R. K. (1968).—Initial and residual effects of superphosphate on a Townsville lucerne pasture in north-eastern Queensland. *Aust. J. exp. Agric. Anim. Husb.* 8:521-27.

JONES, R. K. (1973).—Studies on some deep sandy soils in Cape York Peninsula, North Queensland. 2. Plant Nutrient status. *Aust. J. exp. Agric. Anim. Husb.* 13:89-97.

JONES, R. K., and ROBINSON, P. J. (1970).—The sulphur nutrition of Townsville lucerne (*S. humilis*). *Proc. XI int. Grassld Congr.*, Surfers Paradise, 1970. P. 377.

MARTIN, W. E., MCLEAN, J. G., and QUICK, J. (1965).—Effect of temperature on the occurrence of phosphorus-induced zinc deficiency. *Proc. Soil Sci. Soc. Am.* 29:411.

NORMAN, M. J. T., and ARNDT, W. (1959).—Performance of beef cattle on native and sown pasture at Katherine, N.T. *Div. Land Res. Reg. Surv. C.S.I.R.O. Aust. Tech. Pap.* No. 4.

PERRY, R. A., and LAZARIDES, M. (1964).—Vegetation of the Leichhardt-Gilbert Area. In *General Report on Lands of the Leichhardt-Gilbert Area, Queensland, 1953-54, Land Res. Ser. C.S.I.R.O. Aust.* No. 11. Pp. 152-91.

PERRY, R. A., SLEEMAN, J. R., TWIDALE, C. R., PRICHARD, C. E., SLATYER, R. O., LAZARIDES, M., and COLLINE, F. H. (1964).—General Report on Lands of the Leichhardt-Gilbert area, Queensland, 1953-54. *Land Res. Ser. C.S.I.R.O. Aust.* No. 11.

SHAW, N. H. (1961).—Increased beef production from Townsville lucerne (*Stylosanthes sundaica* Taub.), in the spear grass pastures of central coastal Queensland. *Aust. J. exp. Agric. Anim. Husb.* 1:73-80.

SHAW, N. H., GATES, C. T., and WILSON, J. R. (1966).—Growth and chemical composition of Townsville lucerne. 1. Dry matter yield and nitrogen content in response to superphosphate. *Aust. J. exp. Agric. Anim. Husb.* 6:150-6.

WEBB, A. A. (1975).—Studies on major soils of the Forsayth Granite. 1. Morphological and chemical properties. *Qd. J. agric. Anim. Sci.* 32(1):27-35.

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