RESPONSES TO PHOSPHORUS, COPPER AND POTASSIUM ON A GRANITE LOAM OF THE WET TROPICAL COAST OF QUEENSLAND

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ABSTRACT

Attempts to establish improved pasture on a dark grey sandy loam derived from granite have not been successful. Results from two experiments on this soil type confirmed the severe phosphorus (P) deficiency and showed that copper (Cu) and potassium (K) were also limiting plant growth. The effect appears to be an additive one. The legumes responded to Cu in the presence of additional P and K only in the presence of both Cu and P. Guinea grass responded to additional K when the P status was adequate but not to Cu.

INTRODUCTION

A phosphorus (P) deficiency in soils of granitic origin in the wet tropical coast of Queensland has been recognised for some time (Kerr and von Stieglitz 1938; Sweeney 1961; and Grof 1965). However, attempts to etablish a guinea grass (*Panicum maximum*) — molasses grass (*Melinis minutiflora*) — centro (*Centrosema pubescens*) — stylo (*Styloanthes guyanensis*) pasture on a dark grey sandy loam derived from granite at Tully River Station failed even though superphosphate which contains 9.6% P was applied at the rate of 2 cwt/acre. Since climatic conditions were favourable and careful agronomic practices were employed, a plant nutritional problem was suspected and experiments to investigate the status of essential plant nutrients in the soil were instigated.

The experimental results should have wide application over large areas of similar country found along the wet tropical coast.

Area Description

The climate is wet tropical, with rainfall ranging from 100 to 200 inches per annum. The distribution is markedly seasonal, most rain falling in the period from January to March. Mean annual maximum and minimum temperatures approximate 85°F and 65°F respectively.

The natural vegetation is light layered sclerophyll forest with messmate (*Tristania suaveolens*) occurring most frequently. She oak (*Casuarina littoralis*), wattle (*Acacia flavescens*), stringybark (*Eucalyptus pellita*) and bloodwood (*Eucalyptus intermedia*) are also present. The herbaceous layer consists mainly of spear grass (*Heteropogon*), kangaroo grass (*Themeda*) and grass tree (*Xanthorrhoea*).

The soil is derived from an undifferentiated pink, leucocratic aphyric granite described by De Keyser (1964) as an alkali granite or alaskite, composed of quartz, perthitic potash feldspar, albite, and very little biotite. The first 6" of the soil profile is a very dark grey (10 YR 3/1)* sandy loam. This changes to a dark greyish brown (10 YR 4/2) sandy clay loam at 6", a brown (7.5 YR 4/4) sandy clay loam at 15", and a strong brown (7.5 YR 5/6) clay loam at 30".

*Munsell colour notation.

Analyses of a sample of soil from the experimental site are given in Table I.

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TABLE 1

Analyses of a Granitic Soil in the Wet Tropical Coast of N.E. Qld.

Profile Depth	pH (k)	Avail. P (ppm P)	N %	C % (W & B)	T.E.C. m.e. %	exch. K m.e. %	Clay %	Silt %	Fine Sand	Coarse Sand
		(s)	(n)	(z)	(t)	(t)			%	%
0"–6"	5.3	3.9	0.130	2.34	10.2	0.03	13	11	15	61
6"–15"	5.0	2.2	0.055	1.03	7.4	0.01	24	5	14	58
15"–30"	5.0	1.3	0.020	0.29	2.3	0.01	30	8	10	53
30"–38"	5.2	2.2	0.014	*	*	0.01	13	11	15	61

(k) 1:2.5 H_2O
(s) B.S.E.S. N/100 H_2SO_4 extract
(n) Kjeldahl copper catlyst
(t) Beckwith R.S. (1964)
(r) Bouyoucos
(z) Walkley A. (1947)
*not determined

MATERIALS AND METHODS

Two trials were run consecutively. The first was a general nutritional experiment using an indicator plant species sensitive to nutritional deficiencies. This was followed by an experiment in which those elements found deficient in the first experiment were applied at different rates to a suitable commercial pasture mixture for that area. Superphosphate mentioned in this paper is ordinary superphosphate and not Mo super.

The trial area had received a dressing of superphosphate at the rate of 2 cwt per acre two years previously.

General Nutritional Experiment

Eight elements were applied as a $\frac{1}{2}$ x 2^7 factorial arrangement in a randomized block design to 20 x 25 link plots. Since a P deficiency was known superphosphate was applied as a basal dressing at the rate of 4 cwt/acre (43 lb P/ac). A purer source of P was not available at the time. The fertilizer treatments are given below.

Treatment	*Element*	*Fertilizer*	*Rate of Fertilizer Application*
1	Ca	$CaCO_3$	0 and 10 cwt/acre
2	Mg	$MgSO_4$	0 and 2 cwt/acre
3	K	KCl	0 and 1 cwt/acre
4	Cu	$CuSO_4 . 5H_2O$	0 and 7 lb/acre
5	Zn	$ZnSO_4 . 5H_2O$	0 and 7 lb/acre
6	Mo	MoO_3	0 and 0.5 lb/acre
7	Mn	$MnSO_4$	0 and 7 lb/acre} 14 lb per acre
	B	$Na_2B_4O_7 . 10H_2O$	0 and 7 lb/acre} of the mixture

Siratro (*Phaseolus atropurpureus*) was chosen as the indicator plant. It has the advantages of being fairly sensitive to most nutrient deficiencies, gives good growth in this area for at least the first twelve months and accounts for nutritional requirements of the legume — *Rhizobium* symbiosis to be taken into consideration when assessing the nutritional status of the soil.

The trial area received two cultivations prior to sowing in March 1965. Superphosphate and inoculated seed were broadcast separately by hand and raked into the soil. The fertilizer treatments were then broadcast on the soil surface, beginning with the macroelements and ending with the microelements. There was no movement over the trial area until after sampling was completed.

Sampling for dry matter yield of plant tops took place at the time of first flowering in July 1965. This sampling consisted of cutting two 5 x 5 link quadrats per plot and weighing the oven dried material. Visual ratings of seed production and leaf marginal scorching were made by one observer.

Fertilizer Rate Trial

Phosphorus (P), potassium (K) and copper (Cu) were applied in a 4 x 3^2 complete factorial arrangement to a guinea grass (*Panicum maximum* var. *typica*) — stylo (*Stylosanthes guyanensis* ssp. *guyanensis*) pasture mixture planted in 20 x 25 lk plots. A randomized block design was used with 3 replicates. The treatments were as follows:

P_0 = 0
P_1 = 3 cwt superphosphate/acre = 32 lb P/acre
P_2 = 6 cwt superphosphate/acre = 64 lb P/acre
Cu_0 = 0
Cu_1 = 10 lb $CuSO_4$ $5H_2O$/acre = 2.5 lb Cu/acre
Cu_2 = 40 lb $CuSO_4$ $5H_2O$/acre = 10.0 lb Cu/acre
K_0 = 0
K_1 = 50 lb KCl/acre = 26.2 lb K/acre
K_2 = 100 lb KCl/acre = 52.4 lb K/acre
K_3 = 200 lb KCl/acre = 104.8 lb K/acre

A guinea-stylo pasture was chosen as an indicator of fertilizer requirements because it is considered a suitable commercial pasture for the particular area. The most common superphosphate dressing for pasture establishment in the wet tropical coast is 3 cwt per acre and single commercial dressings exceeding 6 cwt superphosphate per acre are unlikely. Copper is commonly applied at rates of around 10 lb copper sulphate per acre. However, dressings as high as 40 lb are being recommended for sugar cane (Egan and Whitaker 1961) and it was thought that guinea grass may also respond to heavier applications. Potassium is the most expensive of the three elements and was studied in greater detail.

An area adjacent to the preliminary nutritional experiment was cultivated and sown to the guinea-stylo pasture mixture in early January 1967. The fertilizer was broadcast on the surface of the plots immediately after the seed was raked into the soil. Sampling for dry matter yield took place in mid June of the same year by cutting five 5 x 2 link quadrats per plot, sorting the plant material into grass and legume components and weighing the oven-dried material. The dry material was ground and analysed for N, P and K by the methods described by Le Poidevin and Robinson (1964).

RESULTS

General Nutritional Experiment

Mean dry matter yields (lb/acre) shown below, indicate an outstanding response to Cu in the presence of added P. No other nutrient treatment by itself had a significant effect on plant growth, but once Cu had been applied there was an additional response to K.

	K_0	K_1
Cu_0	236.5	227.8
Cu_1	484.9	635.3

L.S.D. (5%) 117.6, (1%) 158.6

Seed production was greatly stimulated by applying Cu. Rating plots 1 to 4 on the basis of seed pods per plot on an ascending scale resulted in a mean rating of 3.2 for plots which received Cu and 1.4 for those where none was applied.

Many of the siratro leaflets had a markedly scorched appearance. The first development appeared to be an interveinal chlorosis in that part of the lamina furthest from the petiole. This later developed into necrotic areas on the margin of the leaflet. Plots which received both Cu and K were least affected.

Fertilizer Rate Trial

Mean effects of the fertilizer treatments are shown in table II.

TABLE 2

Effects of P, Cu and K levels on D.M. Yield and Chemical Composition of the Pasture Components

Treatment	Yield (lb D.M./ac)			P (%)		K (%)		N (%)	
	Guinea	Stylo	Total	Guinea	Stylo	Guinea	Stylo	Guinea	Stylo
P_0	516	456	972	0.11	0.15	2.36	1.77	1.76	2.29
P_1	1442	476	1918	0.12	0.20	2.01	1.52	1.45	2.34
P_2	1861	467	2328	0.15	0.23	1.79	1.34	1.22	2.32
L.S.D. 5%	428	155	438	0.02	0.02	0.23	0.16	0.20	0.13
1%	572	207	587	0.03	0.03	0.31	0.21	0.26	0.19
Cu_0	1125	307	1432	0.13	0.20	2.05	1.66	1.45	2.29
Cu_1	1318	572	1890	0.12	0.19	2.01	1.47	1.49	2.29
Cu_2	1376	520	1896	0.13	0.19	2.10	1.49	1.48	2.36
L.S.D. 5%	428	155	438	0.02	0.02	0.23	0.16	0.20	0.13
1%	572	207	587	0.03	0.03	0.31	0.21	0.26	0.19
K_0	936	374	1310	0.13	0.20	1.73	1.10	1.59	2.36
K_1	1345	470	1815	0.12	0.18	1.96	1.43	1.43	2.25
K_2	1293	504	1797	0.12	0.20	2.18	1.63	1.54	2.35
K_3	1519	517	2035	0.14	0.20	2.36	2.00	1.34	2.30
L.S.D. 5%	494	178	505	0.03	0.03	0.27	0.18	0.23	0.15
1%	663	239	678	0.03	0.03	0.36	0.25	0.30	0.21

The overall highly significant growth response of guinea grass to increased superphosphate is clearly seen but there is no apparent effect on stylo yield. The reverse applies when Cu is considered. Guinea grass did not respond whereas the growth response by stylo was highly significant but with no difference between the 10 and 40lb $CuSO_4$ per acre levels. The main effect of K is on the guinea grass yield which was increased by all K treatments but only the K_3 treatment was significantly greater than the K_0. The effect of K on stylo dry matter production was positive but non-significant.

Chemical analyses showed increased P and K percentages with increased P and K fertilizer applications. Percentage K in stylo was reduced by increasing P and Cu applications and in guinea grass by increasing P application.

Guinea grass N content was also diluted by increasing P applications. The most interesting effect is the K dilution and this is shown more clearly in table 3. The dry matter yields given in this table also vary according to the fertilizer treatment but although the trend is constant, the differences are not statistically significant.

TABLE 3

The effect of some P, K and Cu fertilizer combinations on yield and K concentration in guinea grass and stylo

Treatment		Stylo		Guinea	
		Cu_0	Cu_1	Cu_0	Cu_1
		K concentration (%)			
K_0	P_0	1.35	1.48	1.95	2.34
	P_1	1.39	1.26	1.30	1.74
	P_2	1.23	0.59	1.53	1.20
K_2	P_0	1.87	1.97	2.64	2.73
	P_1	1.75	1.37	2.32	1.88
	P_2	1.51	1.21	1.77	1.87
		Yield (lb D.M./acre)			
K_0	P_0	279	466	234	241
	P_1	320	474	379	1782
	P_2	190	380	846	1662
K_1	P_0	390	316	388	257
	P_1	305	604	1213	1284
	P_2	378	507	2633	2390

DISCUSSION

The level of Cu in this soil is inadequate for satisfactory first year growth of siratro and stylo but there appears to be sufficient for guinea grass. Deficiency of Cu also depressed seed production of siratro. Results suggest that applications of copper sulphate in excess of 10lb per acre are wasteful on this soil type. Copper applications brought about little change in the legume N percentage but yield in terms of lb N per acre was greatly increased. Nitrogen levels in guinea grass appear satisfactory and indicate a good initial supply of N in the soil.

The effect of K on legume growth is more complex. Siratro is highly responsive to K but only in the presence of additional Cu. This suggests that once the Cu deficiency is removed, additional growth is made and siratro becomes K deficient. No significant dry matter response by stylo was recorded but there was a significant response to K from guinea grass. However, chemical analyses of both species show a K dilution with increasing dry matter yields even at high rates of K fertilizer application. This effect is most marked in stylo when it received both Cu and P fertilizers and in guinea grass when it received additional superphosphate. It is therefore possible that the dry matter response of stylo to K is limited by competitive effects from the associated guinea grass. The trend of stylo dry matter production shown in table 3 lends support to this statement.

The application of either Cu or K alone did not prevent or retard the development of necrotic margins taken to be a K deficiency in siratro. However, in the presence of Cu, the plant appeared to be capable of utilizing the additional K and the symptoms disappeared. There was also some interveinal chlorosis in guinea grass and chlorotic patches on stylo leaves but the treatment effects were not clear.

Phosphorus is summarily regarded as the most deficient element in this area, but its true effect in these trials was undoubtedly masked to some extent by the aerial application mentioned earlier. In fact, a significant growth response from stylo to additional P was not measured. Stylo is very efficient at extracting P from the soil (C. S. Andrew, personal communication) and it almost certainly benefiting from the earlier dressing. However, the P percentage in stylo which did not receive P experimentally was low. It was especially low in those plants which received additional Cu but no additional P. Data in table 3 also suggests a growth response in the presence of Cu. In guinea grass, both levels of superphosphate application produced significant increases in dry matter yield. It therefore appears likely that the growth response from stylo is again masked by competition from guinea grass. Work by Andrew and Robins (1969) with *Stylosanthes humilis* supports this reasoning. Assuming *S. humilis* and *S. guyanensis* have equivalent P requirements which seems reasonable from experience (C. S. Andrew, personal communication), from table 2 the only significant difference in %P is between P_0 and P_1 or P_2. P_0 has a P value below the critical % (0.17%) while all other treatments are above. Therefore, a response would be expected in the first instance but not subsequently.

From these two experiments it is evident that except for N, the other plant nutrients required for the establishment of improved pastures in this soil are contained in commercial grades of straight superphosphate, muriate of potash and copper sulphate. It should be remembered that superphosphate alone can satisfy a plant's requirements for calcium, sulphur and sometimes zinc as well as P. Unless superphosphate is applied, improved pasture species will not grow or only poorly on this soil. The increased legume growth and consequently increased symbiotic N fixation due to it, makes copper sulphate the next most important fertilizer. Stylo responds to copper sulphate on this soil after receiving only 2 cwt superphosphate per acre. Muriate of potash also increases the growth of legumes but only after superphosphate and copper sulphate have been applied. Of the species studied, guinea grass has the greatest requirement for muriate of potash.

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REFERENCES

ANDREW, C. S. and ROBINS, M. F. (1969) — The effect of phosphorus on the growth and chemical composition of some tropical pasture legumes. Part I. Growth and phosphorus critical percentages. *Australian Journal of Agricultural Research* **20** (4): 665-674.

BECKWITH, R. S. (1964) — Methods of Chemical Analysis. Bulletin of the Commonwealth Bureau of Pasture and Field Crops. No. 47: 210.

EGAN, B. T. and WHITAKER, G. H. (1961) — Copper deficiency in the Mossman area and its control. Proceedings of the Queensland Society of Sugar Cane Technologists, Bundaberg. 133-7.

GROF, B. (1965) — Establishment of legumes in the humid tropics of north-eastern Australia. Proceedings of the IXth International Grasslands Congress 1137-42.

KERR, H. W. and VON STIEGLITZ, C. R. (1938) — The laboratory determination of soil fertility. Bureau of Sugar Experimental Stations, Queensland. Technical Communication No. 9

KEYSER, F. DE (1964) — Innisfail, Queensland Sheet SE/55-6 Explanatory notes. 1: 250,000 Geological Series. Bureau of Mineral Resources, Geology and Geophysics, Australia.

LE POIDEVIN, N. and ROBINSON, L. A. (1964) — Folair analysis procedures as employed on the Booker group of sugar estates in British Guiana. Part I. Sampling and analytical techniques. Fertilite No. 21.