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PHOSPHORUS SORPTION AND PHOSPHORUS REQUIREMENTS OF MAJOR TOBACCO SOILS IN NORTH QUEENSLAND

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SUMMARY

From phosphorus sorption curves a supernatant solution phosphorus concentration of 0·11 p.p.m. corresponded to 90% maximum yield of field-grown tobacco.

Nineteen virgin sites in the Mareeba-Dimbulah area were sampled to cover the range of major tobacco soils. Field application rates required for 90% maximum yield at each site were calculated from the phosphorus sorbed by the soil at a supernatant solution phosphorus concentration of 0·11 p.p.m. The rates varied from 5 to 43 kg P ha^{-1}. Agricultural implications of these results are discussed.

I. INTRODUCTION

Critical acid extractable (Kerr and von Stieglitz 1938) and bicarbonate extractable (Olsen *et al.* 1954) phosphorous levels for maximum yield of tobacco have been determined for one of the major soil types of the Mareeba–Dimbulah area (Tonello, Warrell and McNee 1981), and therefore similar soils can be classified as responsive or non-responsive to phosphorus fertilizer.

However, field trials relating extractable phosphorus to rate of application are necessary if amounts of fertilizer are to be predicted. As the relationship between extractable phosphorus and phosphorus requirement may vary from one soil type to another (Helyar and Spencer 1977, Ozanne and Shaw 1968), time-consuming phosphorus rate field experiments would need to be carried out on the major soil types of the area.

An alternative approach is based on the premise that the phosphorus fertilizer requirement of a soil should be directly related to the amount of phosphorus sorbed by the soil at a supernatant solution phosphorus concentration found to be non-limiting to plant growth (Beckwith 1965). This concentation is determined by correlating supernatant solution concentrations derived from sorption curves with yield data from field trials. Ozanne and Shaw (1967) successfully used the amount of phosphorus sorbed by soils at 0·3 p.p.m. for predicting the fertilizer requirements of subclover (*Trifolium subterraneum*) pastures, while White and Haydock (1968) found phosphorus sorbed at 0·08 p.p.m. was well correlated with phosphorus required by Siratro (*Macroptilium atropurpureum*) pastures.

The aims of this work were to determine (1) the supernatant solution phosphorus concentration which corresponded to 90% maximum yield of field-grown tobacco; (2) the range in phosphorus sorbed at this supernatant solution concentration by the major tobacco soils and thus the range of application rates required by these soils.

II. MATERIALS AND METHODS

Field experiments

Results were obtained from two series of field trials.

SERIES 1 trials comprised three successive crops of tobacco (cv. CSIRO 40 T) grown at Southedge Tobacco Research Station on a red earth of granitic origin, locally named Morganbury loamy sand (McDonald 1976). The trial design was a 7 x 3 randomized block for the first two crops and a 7 x 3 split plot replicated three times for the final crop. Individual main treatment plots were 10 rows of 22 plants (total) and two rows of 12 plants (datum). The plant and row spacings were 0·53 m and 1·2 m respectively.

Nil, 50 and 100 kg P ha^{-1} was applied as single superphosphate (9·6% P) to give treatment combinations detailed in table 1. Nitrogen as sodium nitrate was applied to the first two crops at 34 kg N ha^{-1} and to the third crop at 44 kg N ha^{-1}. Potassium as potassium sulphate was applied at the rate of 112 kg K ha^{-1} per crop.

Fertilizer was band-applied beside the plant row in August each year, following transplanting of tobacco from the seedbed. Conventional cultural practices were followed throughout the growing season. Leaves from the four commercial plant positions were harvested, flue-cured and weighed.

Soil samples (0 to 15 cm) were taken in July 1973 and July 1974 from all plots. Each sample consisted of 20 random cores. Samples from each treatment were bulked across reps and sorption curves were determined (see Analytical methods).

SERIES 2 trials consisted of phosphorus rate experiments at four district sites for a single season. Site and cropping details are presented in table 2. The trial designs were 6 x 3 randomized blocks for sites I, II and III and a 10 x 3 randomized block for site IV. Plot size varied from four rows of 20 plants to six rows of 12 plants (total) and from two rows of 16 plants to four rows of eight plants (datum), depending on site. The plant and row spacings were 0·53 m and 1·2 m respectively.

TABLE 1

PHOSPHORUS TREATMENTS (kg P ha^{-1}) OF SERIES 1 TRIALS

1st crop (1972–73)	2nd crop (1973–74)	3rd crop (1974–75)
0	0	Each main treatment split to receive three phosphorus levels: 0, 50, 100.
50	0	
50	50	
50	100	
100	0	
100	50	
100	100	

Phosphorus application rates were 0, 20, 40, 60, 80 and 100 kg P ha^{-1} on sites I, II and III and 0, 10, 20, 30, 40, 50, 60 70 80 and 90 kg P kg^{-1} on site IV. Application rates of nitrogen and potassium are shown in table 2. Single superphosphate, sodium nitrate and potassium sulphate treatments were applied in bands beside the plant row in September following transplanting of the tobacco from the seedbed. Conventional cultural practices were followed throughout the growing season. Leaves from the four commercial plant positions were harvested, flue-cured and weighed.

TABLE 2

SITE AND CROPPING DETAILS OF SERIES 2 FIELD TRIALS

Site	Soil type*	Crop history	Basal fertilizer	Variety	Planting date
I	Dimbulah sandy loam	3–4 tobacco crops	45 kg N ha^{-1}; 150 kg K ha^{-1}	Hicks Q34	24 Aug 73
II	Dimbulah sandy loam	10 tobacco crops	55 kg N ha^{-1}; 146 kg K ha^{-1}	Sirone 2	13 Aug 74
III	Morganbury loamy sand	4–5 tobacco crops	45 kg N ha^{-1}; 120 kg K ha^{-1}	CSIRO 40T	2 Sep 74
IV	Mount Aunt complex	cleared, no cropping	80 kg N ha^{-1}; 165 kg K ha^{-1}	Sirone	1 Aug 75

*McDonald (1976)

Composite (0 to 15 cm) soil samples consisting of 20 cores were taken at each site before fertilizer application. Phosphorus sorption curves were determined (see Analytical methods).

District soils

Composite (0 to 15 cm) samples, each consisting of 20 cores, were taken from nineteen virgin sites covering the range of major tobacco soils in the Mareeba-Dimulah area. Site details are presented in table 3. The phosphorus sorption curves of the soils were determined (see Analytical methods).

Analytical methods

Phosphorus sorption curves were determined by shaking 4 g of sieved (2 mm) air dry soil for 18 h at 25°C with 40mL of 0·01 M calcium chloride containing graded amounts of phosphorus as potassium dihydrogen orthophosphate. Added phosphorus ranged from 10 to 300 μg P. Following centrifuging at 3000 r.p.m. for 5 min, the phosphorus concentration of the supernatant solution was determined by the John (1970) modification of the colorimetric method of Murphy and Riley (1962). Curves were constructed by plotting phosphorus sorbed (μg P g^{-1} soil added initially—μg P g^{-1} soil remaining in the supernatant solution) versus phosphorus concentration of the supernatant solution (p.p.m.).

The supernatant solution phosphorus concentration at which there was no net gain or loss of phosphorus by the soil was estimated by interpolation from the sorption curves.

Phosphorus sorbed at a supernatant solution phosphorus concentration of 0·11 p.p.m. (designated 'P sorbed') was interpolated from the phosphorus sorption curves of the district soils.

TABLE 3

SITE DETAILS OF DISTRICT SOILS

Site	Location	Soil type	Parent material*
1	Emerald Creek	Shanty fine sand	Metamorphic (schists) + granitic
2	Emerald Creek	Twiddler Hill clay loam ..	Basaltic + metamorphic
3	Emerald Creek	Tinaroo sand	Metamorphic
4	Chewko	Mount Aunt complex	Granitic
5	Chewko	Morgan loamy sand ..	Granitic
6	Tabacum	Masterton fine sandy loam	Metamorphic
7	Tabacum	Springmount sandy loam ..	Metamorphic
8	Mutchilba	Masterton fine sandy loam	Metamorphic
9	Fumar	Fumar loamy sand ..	Granitic
10	Sandy Creek	Dimbulah sandy loam (brown phase)	Granitic
11	Dimbulah	Dimbulah sandy loam (red brown phase)	Granitic
12	Eureka	Dimbulah sandy loam (brown phase)	Granitic
13	Leafgold	Dimbulah sandy loam (grey phase)	Granitic
14	Wolfram Road	Morganbury loamy sand ..	Granitic
15	Leadingham Road ..	Walsh silty loam	Metamorphic
16	Paddy's Green	Morganbury loamy sand (red phase)	Granitic
17	Paddy's Green	Morganbury loamy sand (brown phase)	Granitic
18	Paddy's Green	Morganbury loamy sand (red phase)	Granitic
19	Southedge Research Station	Morganbury loamy sand (grey phase)	Granitic

*McDonald (1976)

TABLE 4

LEAF YIELDS AND SUPERNATANT SOLUTION PHOSPHORUS CONCENTRATIONS

Trial	Applied phosphorus (kg P ha^{-1})	Supernatant solution concentration (ppm P)	Leaf yield (kg ha^{-1})	Relative yield (%)
Series 1, Second Crop	0–0	0·017	374	16·7
	50–0	0·11	2 219	98·9
	100–0	0·21	2 133 (392)*	95·1
Third crop ..	0–0–0	0·015	548	20·1
	50–0–0	0·07	2 182	80·2
	100–0–0	0·16	2 729 (501)*	100·3
Series 2, Site I	0	0·46	3 125	100·8
Site II	0	0·40	2 564	95·8
Site III	0	0·33	1 967	95·8
Site IV	0	0·026	859	35·0

*L.S.D. (P=0·05)

III. RESULTS

Leaf yield

Phosphorus application significantly increased the cured leaf yield of each of the three crops in the Series I experiments and at site IV in the Series 2 experiments (table 4).

Maximum yield at site IV was calculated by fitting a Mitscherlich equation to the yield data:

$$y = a + b\,e^{cx} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where y = yield (kg ha^{-1}); x = applied phosphorus (kg P ha^{-1}) over the range of 0 to 90 kg P $^{-1}$; and a, b and c are constants.

For the equation of best fit, a = 2455; b = –1587; and c = –0·0924 (r^2 = 0·84***, n = 10).

Maximum yield at sites I, II and III were assumed to be the means of the yields of all treatments as there were no significant yield responses to applied phosphorus. The limited number of treatments in the second year of the Series I trials precluded fitting curves to yield data, and maximum yield of the second crop was estimated as the mean of the yields of all plots except the 0-0 plots.

Assuming that acid extractable phosphorus is an index of plant available phosphorus, the maximum yield of the third crop of the Series 2 trials was calculated by fitting a Mitscherlich equation of the same form as (1) above, where y = yield (kg ha^{-1}); and x = acid extr. phosphorus (μg P g^{-1} soil) over the range 6-74 μg P g^{-1} soil.

For the equation of best fit, a = 2718; b = –4158; and c = –0·1041 (r^2 = 0·86***, n = 21).

Relative yield $\left(\dfrac{\text{treatment mean yield x 100\%}}{\text{estimated maximum yield}}\right)$ was calculated for each phosphorus treatment at each site, allowing the data of Series 1 and Series 2 experiments to be combined. Relative yields and corresponding supernatant solution phosphorus concentrations are presented in table 4.

A Mitscherlich equation of the same form as (1) above was fitted to these data, where y = relative yield (%); and x = supernatant solution phosphorus concentration (p.p.m.) over the range 0·017 to 0·46 p.p.m.

For the equation of best fit, a = 98·5; b = –121; and c = –26 (r^2 = 0·93***, n = 10).

The supernatant solution phosphorus concentration corresponding to 90% maximum yield was estimated by interpolation from this equation as 0·11 p.p.m.

District soils

Phosphorus requirements of the district soils were estimated by converting the amount of P sorbed (μg P g^{-1} soil) to kg P ha^{-1} using bulk density measurements and assuming that all applied phosphorus would remain in the 0 to 15 cm layer. These phosphorus requirements are presented in table 5.

TABLE 5

PHOSPHORUS REQUIREMENTS OF DISTRICT SOILS

Site	P sorbed* (μg P g^{-1} soil)	P required† (kg P ha^{-1})
1	22·0	40
2	32·5	43
3	13·0	23
4	6·5	13
5	3·5	7
6	15·0	26
7	7·0	14
8	9·0	18
9	5·5	11
10	5·0	10
11	7·5	15
12	6·5	13
13	2·1	5
14	9·4	20
15	19·0	33
16	14·5	29
17	8·5	18
18	13·5	26
19	3·4	7

*P sorbed at a supernatant solution phosphorus concentration of 0·11 ppm

†P required = (P sorbed) x 1·5 x (Bulk density, 0–15 cm)

IV. DISCUSSION

From the field trial results, a supernatant solution phosphorus concentration of 0·11 p.p.m. is suggested as adequate for 90% maximum cured leaf yield of tobacco. It follows from Beckwith's (1965) suggestion that the amount of added phosphorus required to raise the supernatant solution phosphorus concentration to 0·11 p.p.m. should be directly related to the fertilizer requirements of these soils. The application rates estimated from P sorbed values of the district soils range from 7 to 43 kg P ha^{-1}.

Within the soil types Morganbury loamy sand and Dimbulah sandy loam, estimated phosphorus requirements vary with surface soil colour—being highest for the red phase and lowest for the grey phase. This may be due to differences in the content of iron oxides which are active phosphorus sorption sites. Higher levels of these oxides would be expected in the redder soils causing increased phosphorus sorption and therefore increased fertilizer requirements.

The range of estimated application rates within a soil type indicates that soil type cannot be used solely as an indicator of likely phosphorus requirements. Field trial results can be extrapolated only to soils which have similar P sorbed values although, in practical terms, the range of estimated application rates is not of great significance.

As it is standard practice to apply low analysis fertilizer mixtures (3 N, 6·1 P, 15 K, 12 Ca) at the rate of 1 000 kg ha^{-1} to virgin land before cropping, phosphorus is being applied at 61 kg ha^{-1}. This rate is excessive for all soils, particularly those of low requirement such as soil 5. Maximum fertilizer efficiency would be attained by supplying sufficient phosphorus initially to raise the supernatant solution phosphorus concentration to 0·11 p.p.m. and maintaining this concentration by applying phosphorus at the rates at which it is being removed in harvested plant material and becoming unavailable through leaching losses or slow 'fixation' reactions.

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