QUEENSLAND DEPARTMENT OF PRIMARY INDUSTRIES

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RESIDUAL VALUE OF SUPERPHOSPHATE APPLIED TO TOBACCO ON A GRANITIC SAND IN NORTH QUEENSLAND

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SUMMARY

A glasshouse and a 3-year field experiment was undertaken to determine the residual value and the effect of continued superphosphate applications on tobacco crop performance.

Phosphorus and calcium status of virgin and cultivated soils of granitic origin used for tobacco production was studied, by a subtractive pot technique using tomato as the test plant. Deficiency symptoms and the uptake of calcium and phosphorus were used as measures of the phosphorus and calcium status of the soils.

In the virgin state, all soils were deficient in plant-available phosphorus. The pot experiment showed that previous tobacco cropping and fertilizer practices increased the P and Ca supply to tomato.

The field experiment showed a build-up in soil phosphorus levels with continued superphosphate dressings and a movement of phosphorus down the profile. A linear relationship exists between the total phosphate applied and the soil's residual Olsen and B.S.E.S. extractable P status. When Olsen's and B.S.E.S. P levels were below 4·0 and 19·0 p.p.m. respectively, a response to superphosphate dressings was found. No response occurred when Olsen's P is 8·0 p.p.m. and B.S.E.S. P was 35·7 p.p.m. or more. Between these levels, superphosphate dressings improved early growth and development and hastened crop maturity.

An application of 50 kg P ha^{-1} was sufficient to grow only two successive tobacco crops whereas an application of 100 kg P ha^{-1} was sufficient for at least three tobacco crops. No apparent relationship exists between the cured leaf phosphorus and reducing sugar levels.

In conclusion, the current fertilizer practices are wasteful and apply phosphorus in excess of the tobacco crop's requirements.

I. INTRODUCTION

Before 1950, successful tobacco production in the Mareeba-Dimbulah area was restricted to alluvial soil types close to a reliable water supply. Following the construction of the Tinaroo Falls Dam in 1958 and the subsequent reticulation system, sloping soils of granitic origin were brought into production. Currently, 60% of the Mareeba-Dimbulah tobacco crop is produced on soils of granitic origin (MacDonald, personal communication).

The pattern of land use on tobacco farms involves using granitic soils for tobacco production either 1 in 3 years or for 2 in 6 years. During the intervening period, the land reverts to a native grass fallow.

In the virgin state, the granitic soils of the Mareeba-Dimbulah tobacco producing area are deficient in nitrogen, phosphorus and sulphur (Ward 1967). The fertilization practices adopted on these soils involve the application of a compound fertilizer mixture (3 N, 6·1 P, 15 K, 12 Ca) at rates equivalent to 1 000 kg ha^{-1}.

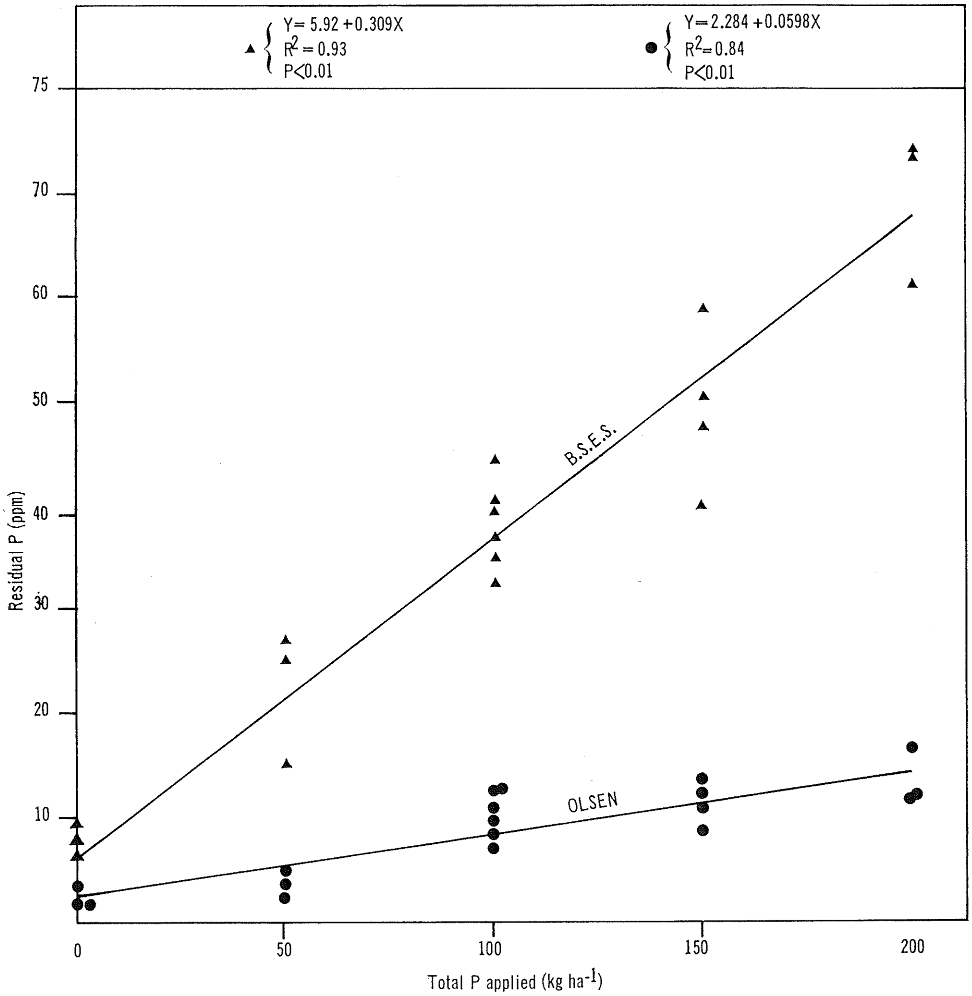

Figure 1. Relationship between total P applied (kg ha^{-1}) and soil residual P status in 0–15 cm depth, prior to third crop.

Under local conditions, a harvested crop will remove approximately 6 to 10 kg P ha^{-1} and 60 to 80 kg Ca ha^{-1} (Tonello, unpublished data). Raper and McCants (1967) reported similar nutrient removal figures. Phosphorus and calcium are applied in excess of the tobacco crop requirements.

Tobacco crops grown on these soils after a history of cropping have cured leaf levels of up to 0·89% P and levels of reducing sugars up to 30% (Tonello, unpublished data). An excess sugar content has been reported to be undesirable because it imparts to the smoke acidic characteristics (Mason and Lea 1955). As Woltz, Reid and Colwell (1948) reported that the phosphorus and sugar content of cured leaf are directly related, the continued application of phosphorus in excess of the tobacco crop's requirements may be partly responsible for the high levels of reducing sugars in locally produced leaf.

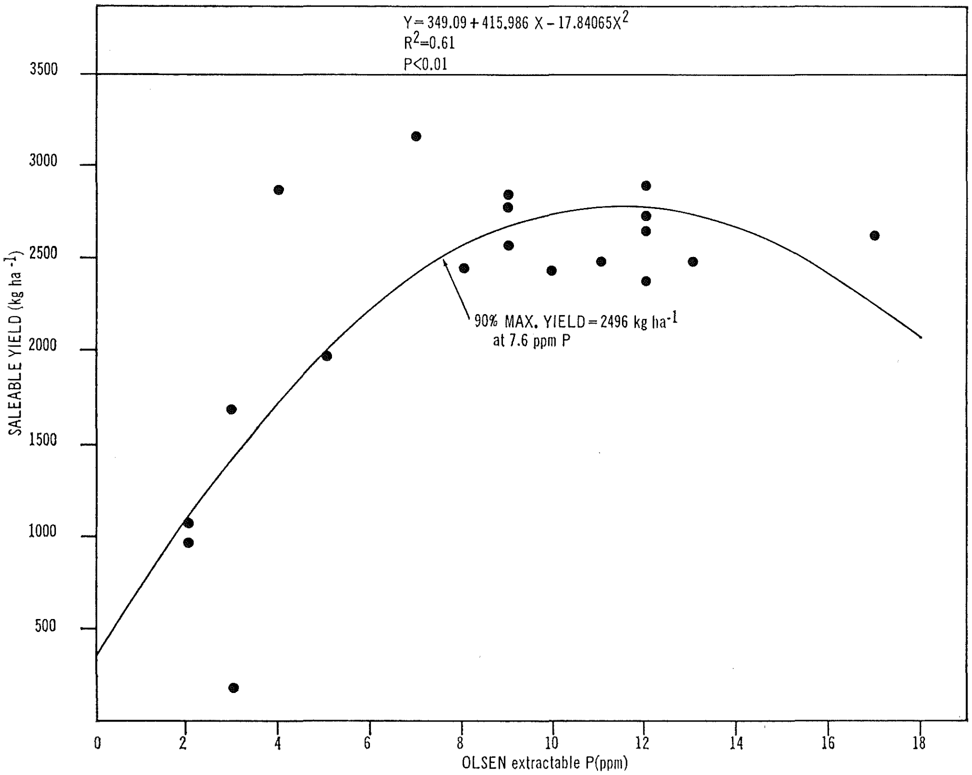

Figure 2. Relationship between soil Olsen extractable P status (p.p.m.) in the 0–15 cm depth and tobacco saleable yield (kg ha^{-1}).

A programme was commenced in 1972 to study the phosphate requirements of tobacco on soils of granitic origin. The aim of the work being reported was to determine the residual value of superphosphate and the effect of continued superphosphate dressings on the tobacco crop performance.

II. MATERIALS AND METHODS

Glasshouse experiment

The soil phosphorus and calcium status of three major tobacco soils with differing cropping histories was assessed by a subtractive pot technique. The experiment, a 3 x 3 x 3 factorial in four randomized blocks was conducted at Southedge Tobacco Research Station under glasshouse conditions during the May-August period in 1972.

Soil Type: S_1, Dimbulah Sandy Loam (McDonald 1967).
S_2, Morganbury Loamy Sand.
S_3, Sorensen Sandy Loam.

Cropping Histories:
None—Soils with no history of cropping or fertilization.
Short—Soils with history of less than five tobacco crops.
Long—More than five tobacco crops.

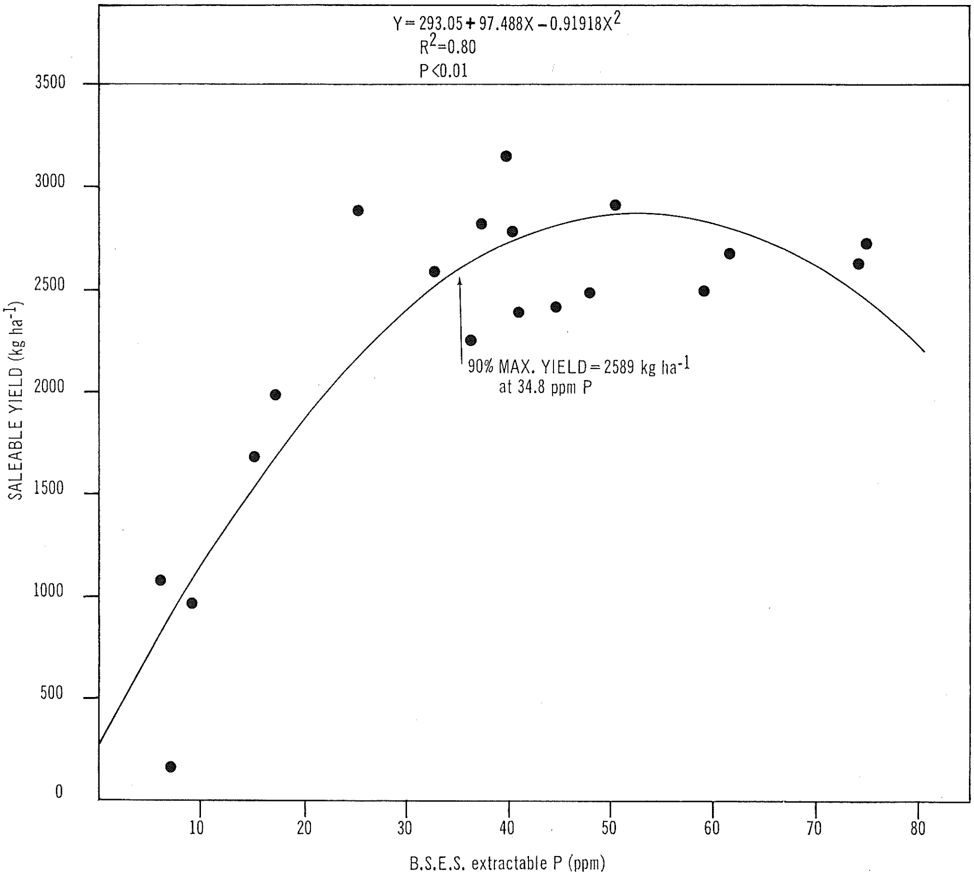

Figure 3. Relationship between soil B.S.E.S. extractable P status (p.p.m.) in the 0–15 cm depth and tobacco saleable yield (kg ha^{-1}).

Nutrient solutions. Nutrient solutions were based on the Long Ashton formula (Hewitt 1952) and modified by Ward (1967). The complete solution (C) was prepared with distilled water using KNO_3 (0.505g per L) Ca $(NO_3)_2.4H_2O$ (1·180 g per L), $NaH_2PO_4.2H_2O$ (0·234 g per L), $MgSO_4.7H_2O$ (0·369 g per L), Iron chelate (0·355 g per L), H_3BO_3 (0·00186 g per L), $MnSO_4.4H_2O$ (0·00223 g per L), $ZnSO_4.7H_2O$ (0·00029 g per L), $CuSO_4.5H_2O$ (0·00025 g per L), $(NH_4)_6 Mo_7 O_{24}.4H_2O$ (0·000035 g per L) and $CoSO_4.7H_2O$ (0·000028 g per L). The minus phosphorus (_P) and minus calcium (_Ca) were prepared by omitting the appropriate chemical reagent. The nitrogen omitted from the (_Ca) solution was replaced by the addition of ammonium nitrate.

Pot technique. Composite soil samples (0 to 15 cm) were collected from each of the soil types of differing land histories. The soils were sieved (2 mm), fumigated (methyl bromide) and 700 grams of air dried soil weighed into 127 mm diameter closed plastic pots. A coarse sand mulch was added to the surface of each pot.

Tomato seeds (cv. Floradel) were sown in a sand culture and germinated with distilled water. At the cotyledon stage, two seedlings were transplanted into the prepared pot. Following establishment, the pots were thinned to one plant per pot. Water was applied by weight on alternate days to return the pots to 80% field capacity. A 50mL aliquot of the appropriate solution was applied to each pot at weekly intervals. The pots were re-randomized at weekly intervals.

Observations of deficiency symptoms (Wallace 1961) were recorded weekly for the duration of the experiment. Plant tops were harvested when plants receiving (C) solution had produced five compound leaves (4 weeks). The plant tops were oven-dried at 70°C for 48 hours and the weight recorded. The samples were ground, digested (micro-Kjeldahl) and phosphorus determined colorimetrically using a chlorostannous reduced molybdophosphoric blue method. Calcium was determined on the atomic absorption spectrophotometer.

Field experiment

The experiment was conducted at Southedge Tobacco Research Station on a red earth of granitic origin, locally named Morganbury Loamy Sand (Northcote classification, Gn. 2·14). The experimental site was cleared in 1968 and then allowed to revert to a native weed fallow until the commencement of the experiment in 1972.

In the field trial, there were several initial phosphate treatments (table 1) applied as granulated single superphosphate (9·6% P). Following harvest of the second crop, each of the main treatments was subdivided into three subtreatments. Nitrogen was applied as nitrate of soda (16% N) at rates equivalent to 34 kg N ha^{-1} on the first and second crops and at 44 kg N ha^{-1} in the third crop. Potassium was applied as sulphate of potash (42% K) at a rate equivalent to 112 kg K ha^{-1} per crop. The nutrient treatments were applied to the tobacco (cv. CSIRO 40T) after transplanting each year. Conventional cultural practices were followed throughout the growing season.

TABLE 1

PHOSPHATE TREATMENTS (kg P ha^{-1})

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

The experiment was a 7 x 3 randomized block for the first two crops and a 7 x 3 split-plot replicated three times in the final crop. Individual main treatment plots were 10 rows of 22 plants (total) and eight rows of 12 plants (datum). After the second crop, they were subdivided into three subplots of four 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.

Before transplanting each year, composite soil samples were collected from 0 to 15, 15 to 30 cm depths for the initial 2 years and from 0 to 15, 15 to 30, 30 to 45 and 45 to 60 cm depths in the final year. At harvesting, the four plant positions were sprayed with a different coloured paint on six plants per plot, selected at random. At the completion of harvest the leaf from each plot was sorted into bundles of similar cured leaf type.

Data recorded included total and saleable cured leaf yields, cured leaf quality, plant heights and flowering time. Tobacco leaf Marketing Board appraisers graded each bundle according to the 1974 price schedule. Leaf quality assessment for each plot, expressed in cents per 500 g, was obtained from the weighted average price of the bundles from the plot. Plant heights were taken on six plants per plot selected at random. Flowering time was determined as the days to 50% flowering.

Cured whole leaf samples from the four plant positions were oven-dried at 70°C, ground, digested (micro-Kjeldahl) and nitrogen and phosphorus determined colorimetrically using a autoanalyser and potassium was determined by flame photometry. Calcium and magnesium were determined on the atomic absorption spectrophotometer. Reducing sugars were determined by an inverse colorimetric procedure using potassium ferri cyanide.

Soil samples were analysed for B.S.E.S. (0·01 N H_2SO_4) and Olsen (O·5M $NaHCO_3$, pH 8·5) extractable P and exchangeable (N NH_4 Cl, pH 7·0) Ca, Mg and K.

III. RESULTS

Glasshouse experiment

Phosphorus deficiency symptoms were recorded on all soils in the virgin state. No calcium deficiency symptoms were recorded in any treatment.

Phosphorus and calcium (table 2) by tomato increased with years of cropping.

TABLE 2

Effect of Land History on P and Ca Uptake (mg/pot). Data Across Soil Types and from (−P) and (−Ca) Treatments only

Nutrient Uptake (mg/pot)	Land history		
	None	Short	Long
P uptake	0·162	1·139	2·915
Ca uptake ..	6·48	8·45	11·09

Nec. Diff. P = 0·05
(i) P uptake 1·478
(ii) Ca uptake 2·656

Field experiment

SOIL DATA. In the virgin state, soil P levels were low, exchangeable K and Mg levels were fair to low and exchangeable Ca levels were considered fair (table 3). Site variability was low.

TABLE 3

SOIL CHEMICAL PROPERTIES (p.p.m.) BEFORE FIRST PLANTING (JULY 1972)

Depth (cm)	P (p.p.m.)		Exchangeable (p.p.m.)		
	Olsen's	B.S.E.S.	K	Ca	Mg
0–15	1	6·5	47	189	31
15–30	1	2·8	40	151	29

Superphosphate dressings increased the soil phosphorus levels. Figure I shows the linear relationship between total phosphate applied as superphosphate and the Olsen and B.S.E.S. extractable P status before the third crop. There was some evidence that P moved (soil samples show a movement of B.S.E.S. extractable P) down the profile into at least the 30 to 45 cm depths (table 4).

The application of superphosphate and potash did not significantly raise the soil exchangeable Ca and K levels.

TABLE 4

CHANGES IN SOIL P STATUS WITH FERTILIZATION AND DEPTH (cm)

Phosphorus kg ha^{-1}		P p.p.m. (July 74)							
		Olsen's				B.S.E.S.			
Aug 72	Aug 73	0–15	15–30	30–45	45–60	0–15	15–30	30–45	45–60
0	0	2·3	1·7	1·2	1·0	7·3	3·8	2·2	3·2
50	0	4·0	2·7	1·5	1·2	19·0	11·3	5·0	4·7
50	50	10·3	3·3	1·3	1·3	40·7	12·7	5·7	4·7
50	100	12·0	5·7	3·3	1·7	57·0	19·7	8·8	6·7
100	0	8·0	3·7	2·3	1·8	35·7	13·8	5·2	6·7
100	50	11·3	6·3	0·8	1·0	52·3	26·7	9·7	6·0
100	100	14·0	8·3	2·0	2·0	70·0	29·2	9·9	6·0
Nec. Diff. P = 0·05		2·52	N.S.	N.S.	N.S.	14·08	11·42	4·90	2·93

Agronomic data

(1) YIELD AND CURED LEAF QUALITY. Phosphorus deficiency symptoms were recorded in all plots which had no superphosphate dressings. The plants were slow growing and stunted, leaves were narrow in proportion to length and dark green in colour. Cured leaf quality was poor and lacked lustre.

Superphosphate dressings increased yields and plant heights, hastened maturity, and improved cured leaf quality (table 5). The residual phosphate from the application of 50 kg P ha^{-1} to the first crop was sufficient to grow one subsequent crop whereas the residual phosphate from the application of 100 kg P ha^{-1} was sufficient for at least two subsequent crops (table 5).

The residual P levels had fallen to 4 and 8 p.p.m. (Olsen) and to 19 and 35·7 p.p.m. (B.S.E.S.) respectively, after the second crop. Quadratic curves fitted well the final year's saleable yield and soil residual Olsen and B.S.E.S. extractable P levels. Figures 2 and 3 show that 90% maximum saleable yield occurred when the soil residual Olsen and B.S.E.S. extractable P level was 7·6 p.p.m. and 34·8 p.p.m., respectively. Heavy phosphate dressings had no consistent effect on cured leaf quality.

TABLE 5

EFFECT OF PHOSPHORUS APPLICATION AND RESIDUAL PHOSPHATE ON TOBACCO CROP PERFORMANCE (THIRD CROP 1974/75)

Fertilization history (kg P ha^{-1}) Yields (kg ha^{-1})					Quality c/½ kg	Flowering time (days)	Plant Ht. cm.
1972–73	1973–74	1974–75	Total	Saleable			
		0	837	548	107·4	78·3	65·0
0	0	50	2 603	2 506	133·8	68·7	105·7
		100	2 694	2 600	135·7	65·7	113·3
		0	2 389	2 182	133·4	64·7	112·7
50	0	50	2 986	2 889	132·0	63·7	116·7
		100	3 226	3 078	139·1	62·7	121·0
		0	2 832	2 729	129·7	61·0	111·7
100	0	50	3 184	3 081	134·1	60·3	116·3
		100	2 925	2 784	133·9	61·0	118·7
		0	2 776	2 673	133·8	61·0	120·0
100	100	50	2 855	2 618	132·9	60·7	120·0
		100	2 834	2 739	136·5	61·0	114·3
Nec. Diff. P = 0·05			470·0	501·0	10·19	4·12	12·80

TABLE 6

CURED LEAF CHEMICAL CONSTITUENTS 3RD CROP (1974–75)

Treatment (kg P ha^{-1})			N%				P%				K%				Ca%				Mg%				Reducing Sugars %			
1972	1973	1974	Lugs	Cutter	Leaf	Tips	Lugs	Cutter	Leaf	Tips	Lugs	Cutter	Leaf	Tips	Lugs	Cutter	Lugs	Tips	Lugs	Cutter	Leaf	Tips	Lugs	Cutter	Leaf	Tips
0	0	0	1·23	1·30	1·55	1·37	0·10	0·10	0·09	0·10	4·0	4·1	2·8	2·5	2·44	1·34	1·65	1·54	0·71	0·41	0·61	0·47	13·9	18·2	20·0	16·5
50	0	0	1·38	1·12	1·17	1·53	0·13	0·17	0·20	0·20	4·6	3·9	2·8	2·3	3·38	2·16	1·85	2·24	0·84	0·46	0·40	0·46	14·5	26·3	23·3	19·8
100	0	0	1·47	1·10	1·15	1·45	0·16	0·22	0·24	0·26	4·3	3·6	2·7	2·5	3·93	2·02	1·73	2·30	0·97	0·46	0·38	0·49	11·6	25·4	26·2	21·3
100	100	100	1·47	0·97	1·08	1·42	0·32	0·36	0·34	0·37	4·1	3·3	2·5	2·7	4·09	2·07	1·83	2·55	0·86	0·41	0·37	0·51	10·3	27·0	26·5	22·0
Nec.Diff. = P0·05			N.S.	N.S.	N.S.	N.S.	0·062	0·061	0·059	0·065	N.S.	N.S.	N.S.	N.S.	0·934	N.S.	N.S.	0·522	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.	4·15

(2) CURED LEAF CHEMICAL CONSTITUENTS. *Nitrogen.* The cured leaf from the first and second crops had a low nitrogen content of $< 1{\cdot}25\%$ N in all plant positions. In the final year the cured leaf nitrogen content was low in the cutter and leaf plant positions (table 6).

Phosphorus. Superphospate dressings increased the phosphorus content of cured leaf in all plant positions (table 6). The cured leaf phosphorus levels at which a yield response to phosphate was recorded were 0·13, 0·17, 0·20 and 0·20 in the lugs, cutter, leaf and tips plant positions, respectively. The phosphorus content of cured leaf generally increased up the plant.

Potassium, calcium, magnesium. Potassium content of cured leaf was sufficient and generally decreased up the plant (table 6). Superphosphate dressings tended to increase the cured leaf calcium content in the lugs and tips position. Calcium content of cured leaf decreased up to the leaf plant position and then increased in the tips. Magnesium content of cured leaf was sufficient and not affected by superphosphate dressings (table 6).

Reducing sugars. Reducing sugar levels in the cutter, leaf and tips plant position were high, irrespective of soil phosphorus status (table 6). There was no significant correlation between cured leaf phosphorus and reducing sugar content in the cured leaf. Reducing sugar levels increased up the leaf plant position and then decreased in the tips.

IV. DISCUSSION

All soils were deficient in plant-available phosphorus in the virgin state. Following cropping and fertilization practices adopted in the area, the plant-available phosphorus and calcium levels have increased. This increase is understandable when one considers that less than one-third of the applied phosphorus and half of the applied calcium are removed in the harvested plant material.

Movement of phosphate down the profile into the 30 to 45 cm depth is evident from the B.S.E.S. extractable P figures, but there is no significant increase in the Olsen extractable P below 30 cm. This suggests that the leached phosphate occurs as calcium phosphate as Chang and Jackson fractionations of inorganic soil phosphate indicate that the B.S.E.S. method extracts these compounds (Bruce and Bruce 1972). However, the Olsen method is not correlated with any Chang and Jackson fraction (Ahmed and Islam 1975) and apparently displaced only surface bound phosphate.

The movement of phosphorus down the profile is in agreement with findings of Ozanne, Kirton and Shaw (1961). This movement is probably due to cultivation, leaching losses and possibly the percolation of precipitates down the sandy profile. The low organic matter, clay and sesquioxide content of the soil in the field experiment suggests that applied P is readily available until it reverts to relatively insoluble calcium compounds. The formation of such compounds may explain the lack of evidence of a build-up in soil exchangeable Ca levels.

When Olsen's and B.S.E.S. P levels were below 4·0 and 19·9 p.p.m. respectively, a response to superphosphate was found. No response occurred when Olsen's P is 8·0 p.p.m. and B.S.E.S. P was 35·7 p.p.m. or more. The lower the soil test value below the 8·0 p.p.m. or 35·7 p.p.m., the more likely a response will occur and the greater the magnitude of this response.

As much as 60% of the Mareeba-Dimbulah crop is produced on soils of granitic origin (McDonald, personal communication) and the phosphate buffering capacities of these soils are low and not markedly different (Moody and Tonello 1981). Therefore, soils similar to that in field site can be classified as responsive or non-responsive to phosphorus fertilizer.

Superphosphate dressings improved early growth and development, increased plant height and hastened maturity. The reducing sugar and phosphorus content of cured leaf were not directly related, which is contrary to the findings of Woltz, Reid and Colwell (1948).

It is apparent that, on soils with a history of tobacco production, the continued application of superphosphate at current rates is unnecessary and phosphorus dressings should be reduced to a maintenance level. The level will depend on the rate at which it is being removed in harvested plant material as well as that becoming unavailable through leaching losses or slow 'fixation' reactions.

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REFERENCES

AHMED, B., and ISLAM, A. (1975).—Extractable phosphate in relation to the forms of phosphate fractions in sole humid tropical soils. *Tropical Agriculture* 52 (2):113-118.

BRUCE, R. C., and BRUCE, I. J. (1972).—The correlation of soil phosphorus with response of tropical pastures to superphosphate on some north Queensland soils. *Australian Journal of Experimental Agriculture and Animal Husbandry* 12:188-194.

MASON, J. T., and LEAR, M. T. (1955).—Twelfth Tobacco Chemists' Research Conference. Duke University, Durham, N.C.

MOODY, P. W., and TONELLO, P. E. (1981).—Phosphorus sorption and phosphorus requirements of major tobacco soils in north Queensland. *Queensland Journal of Agricultural and Animal Sciences* 38 (1):21-27.

OZANNE, P. G., KIRTON, D. J., and SHAW, T. C. (1961).—The loss of phosphorus from sandy soils. *Australian Journal of Agricultural Research* 12 (3):409.

WARD, D. K. (1967).—Studies on the nutrient status of some tobacco soils in far north Queensland. *Queensland Journal of Agricultural and Animal Sciences* 24 (3):253-260.

WOLTZ, W. C., REID, W. A., and COLWELL, W. E. (1948).—Sugars and nicotine in cured bright tobacco as related to mineral element composition. *Soil Science Society of America Proceedings* 13:385-387.

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