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MAIZE FERTILIZER INVESTIGATIONS ON THE ATHERTON TABLELAND, QUEENSLAND

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SUMMARY

Responses ranging from 10 to 47 bus/ac were recorded to nitrogen fertilizer application in three of six experiments conducted from 1960 to 1963 on red loam soils. Lack of nitrogen response in the remaining experiments was associated with either high fertility, incidence of tropical rust, or abnormally dry conditions. Residual effects of nitrogen were small.

Responses to superphosphate varied from nil to 19 bus/ac, and residual responses were evident for up to two years on soils containing less than 70 p.p.m. available P_2O_5.

Potash applications were of little significance.

I. INTRODUCTION

Maize has been grown on the red loams of the Atherton Tableland for up to 70 years. These soils are basaltic in origin and are divided broadly into "scrub" and "forest" soils according to whether the original vegetation was rain-forest or eucalypt forest. The area devoted to maize growing has varied little from 20,000 acres over the past 50 years. On a small portion of this area, maize has been grown in rotation with pastures or peanuts, but most farms have practised maize monoculture. A decline in average yield over a long time has been recognized.

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The principal factors responsible for declining yield are considered to be:

(*a*) depletion of plant foods by continuous cropping to maize over a long period;

(*b*) deterioration in soil structure and associated loss of top soil by erosion;

(*c*) increase in the incidence of cobrot diseases, particularly cobrot caused by *Diplodia zeae;*

(*d*) insufficient attention to seed selection of open-pollinated varieties since the advent of mechanical harvesters;

(*e*) in the past few years, the episodic occurrence of tropical rust (*Puccinia polysora.*)

From an analysis of yields on the Atherton Tableland over a period of 36 years, Simonett and Drane (1952) stated that the decline in yield which could be attributed to time-nitrogen regression, soil structure deterioration and erosion loss was 0·1335 bus/ac/year.

The use of fertilizers on maize has never been widely adopted on the Tablelands. Cartmill (1953) reported that in trials on forest soils over three years, 2 cwt sulphate of ammonia increased the yield by 22, 8 and 16 bus/ac respectively, but only in one year did 2 cwt superphosphate give a significant yield increase (8 bus). In a subsequent trial on eroded scrub soil (Cartmill 1953), 1 cwt sulphate of ammonia increased the yield from 17 to 27 bus/ac; higher applications of sulphate of ammonia did not increase the yields any further. No residual benefits were obtained from the fertilizer applications in these experiments.

In the years 1953-1958, a combined fertilizer and plant population trial was conducted at Kairi Research Station on the Atherton Tableland on land which was subjected to the cropping sequence of 4 years of Rhodes grass/lucerne pasture followed by 5 years of maize (van Haeringen and van der List 1965). A plant population of 12,000/ac consistently outyielded the standard population of 9,000 plants per acre. No significant increases in yield were obtained from applications of sulphate of ammonia, but there was a tendency for sulphate of ammonia combined with the higher plant population to increase yield.

It was not until 1958 that the local open-pollinated strains of Atherton Main Dent and Durum were replaced to a major extent by the hybrids GH128 and GM211. Before tropical rust reduced the yields, these hybrids performed very well, and on the fertile soils of the Research Station yields of 70-80 bus were obtained.

The introduction of these high-yielding hybrids prompted the commencement of a new series of fertilizer trials in 1960. The earlier trials were of an exploratory nature, but subsequently the treatments were modified so as to obtain information regarding the most economical rate of fertilizer use. All of the trials were located on the Queensland Department of Primary Industries Research Station at Kairi, but as far as practicable sites which differed in crop history and fertility were chosen.

This paper deals with the results of fertilizer experiments involving nitrogen, phosphorus and potash carried out from 1960 to 1963.

II. EXPERIMENTAL

Climate and seasonal conditions.—Weather data for the growing periods of the various experimental crops are set out in Table 1. The usual pattern of maize production on the Tablelands is a December planting following early storm rains; general "wet-season" rains then ensue (January-March), and during the subsequent ripening period of the maize, long stretches of wet weather often promote the incidence of cobrots caused by species of *Diplodia* and *Gibberella.*

TABLE 1

RAINFALL, HUMIDITY AND TEMPERATURE DATA

—	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May
1959–60—							
Rainfall (in.)	2·18	10·49	13·13	9·63	3·00	0·80	1·72
Humidity*	80·3	84·9	87·0	87·7	87·7	86·1	83·2
Temperature†	72·2	76·3	74·2	75·4	69·2	66·5	61·9
1960–61—							
Rainfall (in.)	1·29	8·28	5·06	1·58	8·20	2·06	2·11
Humidity	75·0	73·5	73·9	75·5	..	80·8	88·8
Temperature	70·7	71·5	69·1	73·5	68·5	67·5	62·3
1961–62—							
Rainfall (in.)	4·65	3·85	13·05	10·14	4·97	4·00	0·69
Humidity	78·5	74·4	82·8	83·0	78·6	84·5	80·2
Temperature	71·6	72·1	72·0	71·7	70·6	66·5	63·7
1962–63—							
Rainfall (in.)	2·59	2·07	14·67	18·28	5·46	10·10	2·78
Humidity	66·2	66·9	76·6	80·3	85·0	80·4	78·2
Temperature	71·7	72·6	72·4	72·4	71·4	66·2	63·2
Kairi Averages—							
Rainfall (in.)	2·33	4·79	11·18	10·16	9·55	3·38	1·90
Humidity	75·0	77·1	78·9	81·0	83·0	81·9	83·5
Temperature	70·9	72·7	71·9	72·8	70·0	66·5	63·0

* Average hourly relative humidity per month

† Average hourly temperature (°F) per month

The 1960 season was favourable for maize growth; district yields were high and very little tropical rust occurred. Dry conditions during January and February were the dominating factor in the determination of maize yields in the 1961 season; very little tropical rust occurred. The 1962 and 1963 seasons were both characterized by a heavy infestation of tropical rust and yields were low. (Here and elsewhere in this paper, the term "1960 season" refers to the main growing year and not to year of planting. Similar remarks apply to other seasons).

Soils.—Soil analyses for the various experimental sites are set out in Table 2, together with a brief cropping history.

TABLE 2

SOIL ANALYSES ON EXPERIMENTAL SITES (0–10 IN.)

Site	pH	Avail. P_2O_5 (p.p.m.)	Total N (%)	Avail. K (m-equiv. %)	Crop History
Expt. 1 ..	6·4	76	0·15	0·60	Continuous maize
Expt. 2 ..	6·2	56	..	0·51	Continuous maize; slightly eroded
Expt. 3 ..	6·1	46	0·12	0·24	Continuous maize; badly eroded
Expt. 4 ..	6·3	76	0·21	0·86	Rotated land
Expt. 5 ..	6·3	99	0·15	0·61	Continuous maize
Expt. 6 ..	6·4	122	0·15	0·86	Continuous maize, with occasional peanut or lucerne crop

Treatments and planting dates.—The following were the treatments and planting dates for the various experiments:—

Experiment 1

2 replicates of 6N x 2P x 2K

Nitrogen: 0, 40, 80, 120, 160 and 200 lbN/ac

Phosphorus: 0 and 100 lb P_2O_5/ac

Potassium: 0 and 50 lb K_2O/ac

Planting date: December 9, 1959.

Experiment 2

Repetition of experiment 1; planted December 26, 1960.

Experiment 3

Repetition of experiments 1 and 2; planted December 16, 1961.

Experiment 4

2 replicates of 2N x 6P x 2K
Nitrogen: 0 and 50 lbN/ac
Phosphorus: 0, 80, 160, 240, 320 and 400 lb P_2O_5/ac
Potassium: 0 and 25 lb K_2O/ac
Planting date: December 4, 1959.

Experiments 5 *and* 6

7 x 3 randomized block
Treatments: as in Table 3
Planting dates: November 22, 1961, and December 16, 1961, respectively.

TABLE 3

TREATMENTS, EXPERIMENTS 5 AND 6

Code Reference	Basal		Side Dressing
	P_2O_5 (lb/ac)	N (lb/ac)	N (lb/ac)
A	0	0	0
B	20	10	0
C	20	10	20
D	20	10	30
E	20	10	40
F	20	10	50
G	0	30	30

Methods.—The hybrid GH128 was used in all experiments. The plot size was 4 rows of 50 ft, 3 ft 8 in. apart, of which the two inner rows were harvested. The plant population was 12,000/ac and was obtained by planting at a heavy rate and thinning out. Basal applications of fertilizer were made in furrows by hand. The maize was planted on the closed-in furrows so that the fertilizer was about 2 in. below the seed. Side-dressings were given when the plants were 18 in. tall.

In all experiments, sources of nitrogen, phosphorus and potassium were ammonium sulphate, superphosphate and sulphate of potash respectively.

The experiments were harvested by hand.

III. RESULTS

The results of the experiments are presented in Tables 4-9, and may be summarized as follows.

Experiments 1–3

Nitrogen.—In 1960, the application of 40 and 80 lb N/ac increased yield by 31 and 46 bus/ac respectively. Higher applications gave only slight yield increases over 80 lb. Cobrot incidence was reduced significantly by the addition of nitrogen. During the 1961 season no responses were obtained in yield, but in 1962, 80 lb N increased yield by 10 bushels. In neither of these years did the addition of nitrogen reduce cobrot incidence significantly.

TABLE 4

Experiments 1, 2 and 3: Yield and Percentages of Healthy Cobs

Treatment	Yield (bus/ac)			Healthy Cobs (%)		
	Expt. 1 1960	Expt. 2 1961	Expt. 3 1962	Expt. 1 1960	Expt. 2 1961	Expt. 3 1962
N0	41·0	31·1	39·6	82·8	93·4	81·4
N1	72·2	30·7	40·6	89·2	91·7	81·9
N2	87·2	33·2	49·8	90·4	88·5	83·5
N3	88·7	37·8	53·4	91·6	92·9	86·0
N4	95·3	31·9	49·7	90·1	89·8	87·1
N5	95·8	31·8	54·2	91·7	90·2	83·8
P0	81·9	28·7	38·2	91·1	92·2	80·4
P1	78·2	37·1	57·6	87·6	89·8	87·5
K0	78·4	32·2	46·5	89·1	91·7	81·8
K1	81·7	33·6	49·3	89·6	90·5	86·1
Necessary differences for significance—						
N 5%	5·6	N.S.	7·2	3·2	N.S.	8·1
N 1%	7·7	..	9·8	4·4	..	11·0
P, K 5%	3·3	7·1	4·1	1·9	N.S.	4·7
P, K 1%	4·4	9·7	5·6	2·5	..	6·4

In all three experiments, nitrogen applications resulted in dark-green plants, except for the N1 treatments in 1960, the plants of which still showed yellowing of the lower leaves immediately after tasselling.

Phosphorus.—In 1960, 100 lb P_2O_5 resulted in a slight but significant decrease in yield of 3·7 bushels. Cobrot incidence was also increased significantly. In 1961 and 1962, 100 lb P_2O_5 increased yield by 8 and 19 bus respectively. Only in the 1962 experiment did it affect the disease incidence, when it increased the percentage of healthy cobs by 7.

In all three experiments, phosphate hastened the early growth of the plants and reduced the time to maturity. The differences in height due to phosphate were very marked. However, in those cases where phosphate applications did not increase final yield, the non-P treatments were the same height at tasselling time as the treatments with phosphate.

Potassium.—Potash increased the yield slightly but significantly in 1960, when 50 lb K_2O gave a yield increase of 3·3 bushels.

Experiment 4

The results of experiment 4 are given in Table 5. The addition of nitrogen decreased the percentage of healthy cobs by 2·5 but had no effect on yield. All phosphorus treatments were more advanced in the early stages than the non-P treatments. Phosphate reduced the time to tasselling by one week.

TABLE 5

EXPERIMENT 4: YIELD AND PERCENTAGES OF HEALTHY COBS

Treatment	Yield (bus/ac)	Healthy Cobs (%)
N0	96·8	95·2
N1	98·4	92·7
P0	96·8	94·5
P1	97·0	94·7
P2	96·4	93·2
P3	101·3	94·2
P4	98·4	93·7
P5	95.8	93.7
K0	98·1	94·5
K1	97·1	93·5
Necessary differences for significance—		
P 5%	N.S.	N.S.
P 1%	..	..
N, K 5%	N.S.	1·5
N, K 1%	..	2·1

Experiments 5 and 6

The results of experiments 5 and 6 are given in Table 6.

TABLE 6

EXPERIMENTS 5 AND 6: YIELD AND PERCENTAGES OF HEALTHY COBS

Code Reference	Yield (bus/ac)		Healthy Cobs (%)	
	Expt. 5	Expt. 6	Expt. 5	Expt. 6
A	25·5	50·0	62·7	87·7
B	42·7	50·3	71·3	76·0
C	52·7	52·6	80·3	72·7
D	52·5	54·5	80·7	79·0
E	61·5	56·8	84·7	77·0
F	54·1	56·2	76·0	77·3
G	52·5	49·8	76·3	85·0
Necessary differences for significance 5%	14·2	N.S.	9·8	7·0
Necessary differences for significance 1%	20·0	..	13·7	9·7

Nitrogen.—Under the conditions of experiment 5, 10 and 30 lb N increased the yield by 17 and 27 bus respectively. Higher applications did not result in further yield increases. In experiment 6, no significant increases were obtained. Nitrogen increased the percentage of healthy cobs in experiment 5, but in experiment 6 it increased the disease incidence.

Phosphorus.—In experiment 5, no response to phosphate was obtained, but in experiment 6, 20 lb P_2O_5 (treatments B, C, D, E, and F) reduced the percentage of healthy cobs significantly.

Residual Effects, Experiments 2 and 3

In Table 7, the yields and percentages of healthy cobs obtained in experiment 2 for the first and second years after the fertilizer application are set out.

TABLE 7

EXPERIMENT 2: RESIDUAL EFFECT OF FERTILIZER

Treatment	Yield (bus/ac)		Healthy Cobs (%)	
	1st Year 1962	2nd Year 1963	1st Year 1962	2nd Year 1963
N0	34·4	22·1	63·1	86·2
N1	38·2	21·6	63·2	87·9
N2	44·7	26·1	71·8	89·1
N3	49·9	26·1	73·8	90·8
N4	53·7	25·8	80·9	88·9
N5	48·3	26·0	74·1	91·9
P0	41·5	22·6	71·6	89·4
P1	48·3	26·6	70·6	88·8
K0	46·1	25·1	71·2	89·9
K1	43·7	24·2	71·0	88·4
Necessary differences for significance—				
N 5%	10·1	N.S.	7·9	N.S.
N 1%	13·8	..	10·7	..
P, K 5%	5·8	2·9	4·6	N.S.
P, K 1%	7·9	3·9	6·2	..

Nitrogen.—In the first year after the fertilizer application, initial applications of nitrogen in excess of 40 lb still increased yields significantly, and they also reduced the incidence of cobrots. In the second year after application, no responses could be detected.

Phosphorus.—In the first and second years, 100 lb. P_2O_5 applied initially in the 1961 season increased the yield significantly by 7 and 4 bus respectively.

Potassium.—No residual effect occurred.

The residual effects of the various treatments in experiment 3 are summarized in Table 8. The only residual effect was that shown in the first year after the initial application of 100 lb P_2O_5, which was a yield increase of 4 bushels.

TABLE 8

EXPERIMENT 3: RESIDUAL EFFECT OF FERTILIZER

Treatment	Yield (bus/ac)	Healthy Cobs (%)
	1st Year 1963	1st Year 1963
N0	17·5	79·5
N1	17·4	86·1
N2	17·0	88·2
N3	19·7	84·2
N4	19·9	84·5
N5	19·0	85·7
P0	16·4	85·0
P1	20·4	84·4
K0	17·6	85·7
K1	19·2	83·7
Necessary differences for significance—		
N 5% ..	N.S.	N.S.
N 1% ..	..	..
P, K 5% ..	2·7	N.S.
P, K 1% ..	3·6	..

Summary of Nitrogen Responses

The yield responses to nitrogen are summarized in Table 9.

TABLE 9

SUMMARY OF YIELD RESPONSES TO NITROGEN

Year	Site Particulars	Yield, No N (bus/ac)	Yield (bus/ac) Increment Due to						
			10 lb N	30 lb N	40 lb N	50 lb N	60 lb N	80 lb N	120 lb N
1960	Rotated land; 0·21% N ..	96·8				1·6			
1960	Continuous maize; 0·15% N ..	41·0			31·2			46·2	47·7
1961	Continuous maize; slightly eroded	31·1			0			2·1	6·7
1962	Continuous maize; badly eroded; 0·12% N	39·6			1·0			10·2	13·8
1962	Continuous maize; 0·15% N ..	25·5	17·2	27·2	27·0	36·0	28·6		
1962	Continuous maize; occasional peanut or lucerne crop; 0·15% N	50·0	0·3	2·6	4·5	6·8	6·2		

IV. DISCUSSION

In the absence of a heavy infestation of tropical rust, applications of 40 to 80 lb. nitrogen per acre gave economic increases in yield on continuous maize land when seasonal conditions were favourable. Under dry seasonal conditions, as in the 1960-61 season, no response can be expected. Such seasonal conditions are infrequent.

Some indication of the optimum level of nitrogen to apply could be obtained by considering total nitrogen content of the soil, cropping history of the land and yield figures of previous years. However, as tropical rust in some seasons may reduce yield by as much as one-half, it is not possible to predict the extent of yield response to nitrogen. Tropical rust occurred in epidemic proportions in four of the seven seasons from 1958 to 1964.

It is probable that the addition of nitrogen accentuates damage by tropical rust by extending the period and amount of vegetative growth. Black (1957) suggested that the effect of rank vegetative growth may be to raise the relative humidity around the plants, thereby favouring rust infection.

When nitrogen increased yields, incidence of cobrot was reduced. Under conditions of an oversupply of nitrogen, cobrot incidence may increase slightly, as in experiment 4. Cobrot incidence depends to a large extent on the weather conditions prevailing at the optimum stage for disease infection.

The only residual effect of nitrogen occurred in 1962 from applications above 40 lb made in 1961, which was an extremely dry season. It may safely be concluded that the residual effect of nitrogen has little economic significance.

Yield responses to addition of superphosphate were obtained only on experiments 2 and 3, where available P_2O_5 in the soil was initially 56 and 44 p.p.m. respectively. In the other experiments, initial available P_2O_5 was over 70 p.p.m.

The lack of yield response to added phosphate on the soils high in available P_2O_5, even though a growth response was evident up to 6 weeks of age, may be accounted for by the fact that phosphate uptake by the unfertilized plants during the relatively long growing period of the crop was ample.

Other factors in yield response to superphosphate may be deduced. For instance, in experiment 2, phosphate application caused early tasselling and provided the opportunity for good seed setting before the season turned dry. Hastening of maturity due to application of superphosphate may also enable the crop to escape tropical rust infection in some seasons. Early planting may have the same effect.

On the other hand, the data for cobrot infection in experiment 6, where cobrot was increased irrespective of the amount of nitrogen applied, suggest that phosphate application caused the plants to reach a stage favourable for cobrot infection when weather conditions favoured the disease.

In general, the effect of phosphate application was to decrease the incidence of cobrot when the initial phosphate level was low. However, when phosphate applications affected only the vegetative growth pattern, the effect of phosphate on cobrot incidence was not predictable.

Where the initial soil phosphate level was low, phosphate applications had significant effects on yields of one or two succeeding crops.

There was little evidence of potash application affecting yield.

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