

PLANT NUTRITION AND FERTILIZER USAGE WITH SPECIFIC REFERENCE TO MAIZE

(Met opsomming in Afrikaans)

F. J. DIJKHUIS, African Explosives & Chemical Industries, Limited, Research Department, Northrand.

Abstract

The results from nitrogen carrier, phosphate carrier and factorial experiments carried out at the Research Station of African Explosives and Chemical Industries at Bapsfontein showed that the most economical yields of maize planted at the rate of 30,000 plants per morgen were obtained with the application of 100 lb N, 44 lb P and 100 lb K per morgen.

Under the conditions prevailing at the Research Station the time of application of nitrogen is of no importance.

Introduction

The three main groups of agricultural activity in South Africa are animal husbandry, field husbandry and horticulture. The composition of the gross value of production in percentage for 1963/64, 1964/65 and 1965/66 is given in Table 1 (Annual Report, Dept. Agric. Econ. Market, S.Afr. 1965/66).

TABLE 1. Gross value of production in percentage

	% Composition		
	1963/64	1964/65	1965/66
Animal husbandry	47	45	47
Field husbandry	39	40	39
Horticulture	14	15	14

The gross value of field husbandry products during 1965/66 was R407 million, of which 49 per cent or R200 million was earned by maize (Annual Report, Dept. Agric. Econ. Market, S.Afr., 1965/66). These figures show the important role played by maize production in the economic structure. It is therefore distressing that the mean yield realised over the 5 year period 1961/62 to 1965/66 was only 10.9 bags per morgen (Report, Maize Control Board, S.Afr. 1967). Of the major maize producing countries in the world, only Mexico and India showed a lower yield than South Africa over that period (Report, Mealie Board, S.Afr. 1967).

The adoption of better cultivation practices and the use of hybrid seed have enabled farmers in the major maize growing areas in South Africa to obtain yields of over 40 bags per morgen. However, in the favourable season 1963/64 the average yield for the Transvaal Highveld, the North Western Free State and the Western Transvaal was only 14.02, 12.96 and 15.80 bags per morgen respectively (Report, Maize Control Board, S.Afr. 1967). These figures indicate that in general, the methods of maize production are falling short of the requirements.

In this paper the effect of fertilization on maize yields will be discussed assuming that all other production factors, which can be controlled, are optimum.

Maize or any other crop needs to be fed with enough and balanced fertilizer. The ratio between the elements and the amount of fertilizer will change with soil and

plant population, but at any time the plants will have to be able to create the inner balance for optimum physiological activity.

The average amount of fertilizer for all crops used by the farmers in 1965 was approximately 20 lb N, 21 lb P and 14 lb K (total 55 lb) per morgen, while the potential is thought to be 66 lb N, 40 lb P and 29 lb K (total 135 lb) per morgen.

The results of fertilizer experiments with maize carried out on the Research Station of African Explosives and Chemical Industries at Bapsfontein and recommendations made based on these results are presented in this paper.

The soil on the Research Station belongs to the Msinga series. The average rainfall over the 9 year period 1958/59 to 1966/67 was 27 inches.

All experiments were planted mechanically in 3 ft rows with a modified maize planter.

Method, Procedures and Results

Nitrogenous fertilizers

Carriers

In the 1957/58 season an experiment to compare the effect of urea, ammonium nitrate and ammonium sulphate on the yield of maize was started. From the 1962/63 season onwards ammonium nitrate was replaced by limestone ammonium nitrate. The nitrogenous fertilizers were side-dressed at the rate of 100 lb N per morgen, when the maize plants were 12 inches high. At planting a 4:1 mixture of single superphosphate and muriate of potash, at the rate of 800 lb per morgen was banded 2½ inches to the side of and below the seed. The plant population was 30,000 per morgen for the seasons 1957/58 to 1964/65 and 40,000 per morgen in 1965/66 and 1966/67.

The results for the 10 years the experiment has been carried out, are presented in Table 2.

Seed: 1957/58	Mixed Success
1958/59	Sahara
1959/60	Hickory King
1960/61	SA9
1961/62	SA9
1962/63 to 1966/67	SA4

A statistical analysis of the total yields over the first 5 year period showed that the urea treatment out-yielded the control and the other two nitrogen treatments significantly at the 1 per cent level.

During the second 5 year period all nitrogen carriers out-yielded the control significantly in each individual year.

In 1963/64 ammonium sulphate yielded significantly less than urea and in 1964/65 less than urea or limestone ammonium nitrate. The latter two carriers showed no significant difference in yield in any of the 5 seasons.

Nitrogen at the rate of 100 lb N increased the yield of maize on average by 3.8 bags per morgen over the first 5 year period and by 15.9 bags per morgen over the last 5 year period.

TABLE 2. Yield results over 10 year period

Season	Yield in 200 lb bags per morgen				Mean of 2 + 3 + 4 minus 1	L.S.D.	
	1	2	3	4		5%	1%
	No nitrogen	Urea	Ammonium nitrate	Ammonium sulphate			
1957/58	29.6	35.8	32.6	34.2	4.6	4.5	—
1958/59	22.9	26.1	24.1	24.7	2.1	2.3	—
1959/60	12.2	17.0	14.0	13.6	2.7	N.S.	
1960/61	36.7	47.3	47.4	46.3	10.3	4.0	6.0
1961/62	25.9	28.7	23.9	23.9	-0.4	3.3	4.7
Mean	25.5	31.0	28.4	28.5	3.8		
1962/63	29.7	41.0	L.A.N. 40.1	39.5	10.5	5.8	8.3
1963/64	41.4	56.0	52.2	50.6	11.5	5.1	—
1964/65	23.6	45.7	44.6	41.6	20.4	2.4	3.6
1965/66	9.5	12.9	13.2	12.4	3.3	2.1	—
1966/67	12.1	45.5	47.9	45.2	34.1	3.5	5.3
Mean	23.3	40.2	39.6	37.9	15.9		
10 year mean	24.4	35.6	34.0	33.2	9.9		

A comparison of the mean yields for the two 5 year periods shows that during the second period the yield from the no nitrogen treatment decreased by 2.2 bags per morgen, while that from the nitrogen treatments increased by 9.9 bags per morgen.

Both yield components, ear to plant ratio and ear weight contributed to the increase in yield due to nitrogen application. The mean ear to plant ratios and ear weights for the period 1960/61 to 1966/67 are shown in Table 3:

TABLE 3: Ear to plant ratio and ear weight in lb

	No nitrogen	N treatments
Ear to plant ratio	0.87	1.01
Ear weight in lb	0.22	0.29

The whole experiment was limed in September 1960 at the rate of 2 tons per morgen.

Soil samples taken in subsequent seasons gave the following pH figures:

TABLE 4. pH Values

Sampling date	No nitrogen	Urea	Ammonium nitrate	Ammonium sulphate
24.8.1961	6.5	6.3	6.3	6.1
30.5.1962	6.3	6.1	6.2	5.8
9.7.1963	6.3	6.2	L.A.N. 6.1	5.7
25.5.1964	6.0	5.9	5.9	5.6
17.6.1965*	5.4	5.1	5.2	4.7

*pH (KCl).

The figures show that the acidifying effect of urea, ammonium nitrate and limestone ammonium nitrate was small, while ammonium sulphate caused a much greater reduction in pH.

Time of placement (Annual Review 1965, AE & CI).

In another experiment, different times and methods of application of urea and ammonium sulphate were compared for a 5 year period (1958/59 to 1962/63). The same basic dressing of phosphate and potash as described under "carriers" was applied.

The following nitrogen treatments (at the rate of 100 lb N per morgen) were given:

- (i) No N
- (ii) N broadcast and left on the surface before planting.
- (iii) N placed 9 inches deep and 3 inches to the side of the row at planting.
- (iv) N side-dressed and cultivated into the soil when the maize plants were 12 inches high.
- (v) N side-dressed when the plants started tasselling.

Seed: 1958/59 Sahara.
1959/60 Hickory King
1960/61 }
1961/62 } SA4
1962/63 }

The plant population was 30,000 per morgen.

The results over the 5 year period are given in Table 5.

TABLE 5. Mean grain yield in bags per morgen for the period 1958-59 to 1962-63

	Urea	Ammonium sulphate	No N
No nitrogen			24.7
N broadcast before planting	28.9	27.8	
N placed 9 inches deep at planting	27.6	28.4	
N side-dressed when plants 12 inches	29.8	28.6	
N side-dressed when plants tasselling	29.7	28.9	
Mean	29.0	28.4	24.7

Nitrogen increased the yield significantly (1 per cent level) but time and method of application were not important.

Urea and ammonium sulphate gave approximately the same yield.

The increase of 4 bags per morgen due to the application of 100 lb N per morgen is approximately the same as that obtained for the same period in the experiment on carriers discussed.

In another experiment, urea at the rate of 100 lb N per morgen was ploughed down in winter and this treatment was compared with the conventional method of side-dressing the nitrogen fertilizer when the maize plants were 12 inches high.

Sahara was planted in the first season and SA4 in the other seasons.

The results over a 8 year period were as follows: no nitrogen 22.2, nitrogen ploughed in 32.1 and nitrogen side-dressed 32.6 bags per morgen.

The results show (as in the previous experiment) that the time of application of nitrogen is not important under the conditions prevailing at the Bapsfontein Research Station.

The increase in yield due to nitrogen application was 10.2 bags per morgen for the 8 year period. However, over the last 5 seasons the increase was 13.4 bags per morgen (22.0 bags per morgen for control and 35.4 bags per morgen for the N treatments).

Phosphatic fertilizers (Annual Review, 1965, AE & CI).

Comparison of phosphates on soils of different pH.

Over a period of 5 years (from 1960/61 until 1964/65) maize was grown with superphosphate and different rock phosphates on limed (pH in water 6.0) and unlimed (pH in water 5.0) soil.

The rock phosphates used were Foskorite, Morocco and Nova. Morocco rock phosphate was applied in two ways; either at 1 ton per morgen in the first year or in 400 lb per morgen annual dressings.

Foskorite and Nova rock phosphates were applied at 1 ton per morgen in the first year, superphosphate at 400 lb (same quantity as the annual Morocco rock phosphate application) and at 660 lb (same total P content as the annual Morocco rock phosphate application) per morgen annually.

All the plots received 100 lb N per morgen in the form of urea as a side-dressing.

On the limed section the superphosphate at 660 lb per morgen outyielded the rock phosphate treatments and the control significantly in four out of the five years. The mean yields for the 5 year period are given in Table 6.

TABLE 6. Mean yield in bags per morgen, 1960/61—1964/65

Superphosphate (660 lb annually)	37.2
Superphosphate (400 lb annually)	36.3
Morocco rock phosphate (400 lb annually)	33.9
Morocco rock phosphate (1 ton 1st year)	33.6
Nova rock phosphate (1 ton 1st year)	34.2
Foskorite (1 ton 1st year)	29.6
Control (no phosphate)	28.9

On the unlimed section no significant differences in yield were found between superphosphate and the Morocco or Nova rock phosphate treatments in any of the seasons. The mean yields on this section were 3 to 7 bags per morgen lower than on the limed section.

Under both pH conditions Foskorite proved to be inferior to the other phosphate treatments and only slightly better than the control.

Nitrogen, phosphorus factorial

The interaction of nitrogen and phosphorus was studied in an experiment over a 5 year period (1958/59 to 1962/63).

The following levels of fertilizer were used: 0, 44 lb, 88 lb and 132 lb P per morgen (as single superphosphate) and 0, 100 lb and 200 lb N per morgen (as urea). An overall dressing of 100 lb muriate of potash was broadcast and disked in before planting. The superphosphate was banded at the time of planting and the urea was side-dressed when the maize was 12 inches high. The seed used was SA4.

The mean yield for the 5 year period are presented in Table 7.

TABLE 7. Mean grain yield in bags per morgen

	N	N ₁	N ₂	Mean
P ₀	26.12	27.74	29.65	27.84
P ₁	28.31	31.54	32.81	30.89
P ₂	29.10	33.53	33.65	32.09
P ₃	28.59	33.37	31.58	31.18
Mean	28.03	31.55	31.92	

Although five other treatments outyielded the N₁P₁ treatment, the increases in yield did not cover the extra cost due to higher fertilizer rates.

Consequently 100 lb and 44 lb per morgen were the most economical application of nitrogen and phosphorus respectively.

Nitrogen, phosphorus, potassium, lime factorial

This experiment, carried out over a period of 9 years (1957/58 to 1965/66), had a split plot design with a P x L (3 x 2) factorial in whole plots. The whole plots were split into nine sub plots on which an N x K (3 x 3) factorial was laid down. The number of replications was 4.

The following treatments, expressed as rates per morgen were included:

N ₀ 0	P ₀ 0	K ₀ 0	Lime 0
N ₁ 100 lb N	P ₁ 44 lb P	K ₁ 50 lb K	Lime 4000 lb
N ₂ 200 lb N	P ₂ 88 lb P	K ₂ 100 lb K	

The lime which was only applied when the pH (in H₂O) fell below 5.5, was broadcast and ploughed in in the winters of 1957, 1960, and 1961. In June 1966 the pH of the unlimed treatments was approximately 4.0. The phosphorus, in the form of superphosphate, was applied in a band at the time of planting. The nitrogen, in the form of urea, and the potassium, in the form of muriate of potash, were side-dressed by hand and cultivated in when the maize was 12 inches high.

The hybrid SA4 was planted at a plant population of 30,000 per morgen.

The results of this experiment are presented in Tables 8, 9 and 10.

Amongst these ten highest yielding treatments were none which included N₀, P₀ or K₀ (refer Table 10).

The fact that two unlimed treatments were included is difficult to explain, as in general the effect of lime is beneficial.

From the results it can be concluded that N₁P₁K₁L₁ was the minimum fertilizer requirement in this experiment. The mean yield for this treatment was 31.70 bags per morgen. The only treatment which yielded more on an economical basis was the highest yielding, N₁P₁K₂

TABLE 8. Mean grain yield in bags per morgen for the period 1957/58 to 1965/66

P	K	L	N ₀	N ₁	N ₂
0	0	0	21.14	23.61	23.57
0	0	1	23.51	24.86	26.57
0	1	0	22.24	24.99	24.13
0	1	1	26.00	29.14	29.38
0	2	0	22.36	26.18	24.74
0	2	1	26.52	29.80	29.67
1	0	0	23.77	26.37	25.01
1	0	1	25.75	25.98	27.23
1	1	0	21.54	29.25	31.91
1	1	1	28.42	31.70	31.57
1	2	0	21.11	31.05	29.44
1	2	1	30.55	33.83	33.35
2	0	0	24.71	24.71	26.34
2	0	1	25.35	28.01	27.74
2	1	0	24.08	29.18	29.73
2	1	1	27.55	33.16	32.35
2	2	0	22.19	30.80	31.08
2	2	1	29.37	32.84	32.45

TABLE 9. Main effects

N ₀	24.79	P ₀	26.59	K ₀	25.13	No lime	25.67
N ₁	28.61	P ₁	28.20	K ₁	28.10	4000 lb lime	28.97
N ₂	28.58	P ₂	28.31	K ₂	28.76		

TABLE 10. Ten highest yielding fertilizer combinations

Treatment	Yield in bags per morgen
N P K L	
1 1 2 1	33.83
2 1 2 1	33.35
1 2 1 1	33.16
1 2 2 1	32.84
2 2 2 1	32.45
2 2 1 1	32.35
2 1 1 0	31.91
1 1 1 1	31.70
2 1 1 1	31.57
2 2 2 0	31.08

L₁ (33.83 bags per morgen) as the yield was increased by 2.13 bags per morgen at an extra cost of only R1.76 for 100 lb muriate of potash per morgen.

Discussion

In the nitrogen carriers experiment the comparatively low yields during the first 3 seasons must have been due to the fact that varieties instead of hybrids were planted. Although hybrid maize was used in each season of the second 5 year period, the mean yield for the control decreased by 2.2 bags per morgen when compared with the first 5 years, due probably, to the decreasing level of fertility.

Ear to plant ratio is used by plant breeders as a selection criterion. The results in Table 3 show that the earweight should also be considered in this respect, as the response to nitrogen of this variate is more pronounced than that of the ear to plant ratio. The increase in earweight due to 100 lb N per morgen over control was 32 per cent, while the number of ears per plant increased by only 16 per cent.

Under the conditions prevailing at the Bapsfontein Research Station the time and method of application of nitrogen is of no importance.

The results from two factorial experiments show that 100 lb N and 44 lb P were the most economical levels of nitrogen and phosphorus fertilization for 30,000 maize plants per morgen. The N P K L factorial indicated that 100 lb K should be combined with 100 lb N and 44 lb P to obtain a balanced mixture.

It has been noticed, however, that with the increase in plant population in the nitrogen carrier experiment from 30,000 to 40,000 plants per morgen, the plants show nitrogen deficiency symptoms before flowering. An increase of the amount of nitrogen to approximately 150 lb N per morgen might be advisable at this plant population.

Opsomming

PLANTVOEDING EN KUNSMISVERBRUIK MET SPESIALE VERWYSING NA MIELIES.

Die resultate van stikstofdraer, fosfaatdraer en faktoriaalproewe uitgevoer by die proefstasie van Afrikaanse Springstowwe en Chemiese Nywerhede te Bapsfontein, het getoon dat die mees ekonomiese opbrengste van mielies, geplant teen 30,000 plante per morg, behaal is met 'n toediening van 100 lb N, 44 lb P en 100 lb K per morg.

Die grond en die weersomstandighede by die proefstasie is sodanig, dat dit geen verskil maak wanneer die stikstofkunsmis toegedien word nie.

Acknowledgements

The author wishes to thank African Explosives and Chemical Industries, Limited, for permission to publish this paper.

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