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Articles in the field of agricultural economics, suitable for publication in the journal, will be welcomed.

Articles should have a maximum length of 10 folio pages (including tables, graphs, etc.) typed in double spacing. Contributions, in the language preferred by the writer, should be submitted in triplicate to the Editor, c/o Department of Agricultural Economics and Marketing, Pretoria, and should reach him at least one month prior to date of publication.

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Contents

Page

I. ARTICLES

1. An approach for the development of planning standards for a homogeneous farming area:
Part I — M.F. Viljoen, University of the Orange Free State 1
2. Optimal production scheduling in pig production — M.D. Nel, Perdekop Meule and J.A. Groenewald, University of Pretoria 7
3. The effect of the weather on the economic optimum level of fertilizer use — W.L. Nieuwoudt and H.I. Behrmann, University of Natal 14
4. Socialist enterprise forms in agriculture V: The state enterprise as an economy entity — T.I. Fényes, University of the North and J.A. Groenewald, University of Pretoria 17

II. STATISTICS 22

THE EFFECT OF THE WEATHER ON THE ECONOMIC OPTIMUM LEVEL OF FERTILIZER USE

by

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INTRODUCTION

Crop yields in South Africa are more dependent on the weather than is the case in e.g. the United States and Western Europe. To gain an impression of the effect of the weather on crop yields in South Africa, one only has to study the maize yields of the past five or ten consecutive years. For example maize production in kg per ha varied as follows in the Western Transvaal for the most recent five years (1970/71 - 1974/75): 1 853; 2 576; 911; 3 162 and 2 526, respectively.

The purpose of this article is to analyse the influence of the weather on the optimum use of fertilizers.

DATA

Data for this analysis are based on maize/fertilizer trials conducted at Tabamhlope in Natal by Prof. E.R. Orchard, previous head of the Department of Soil Science at the University of Natal. Trials were carried out on a Farningham soil for 15 consecutive years, viz 1956 to 1970. Each of 81 plots received the same treatment during this period. Repetition of the trials made it possible to calculate the optimum long-term application rate of fertilizer and to study the effect of the weather on

economic optimum use of fertilizers.

Another advantage of repetition is that it accounts for retention of nutrients in the soil not utilised by the plants. The elements P, K and L are retained in the soil when not assimilated by plants.

It is therefore essential that trials be repeated for three to at least five years in order that meaningful recommendations may be made. In this context the above-mentioned trials were of significant scientific importance. As the trials started as early as 1956, a standard cultivar of maize (SA 30) was used. An analysis of trials with hybrid seed in the same area showed that hybrid seed produces a substantially higher yield and can assimilate more fertilizer to obtain this yield.¹

RESULTS

To determine the optimum long-term fertilizer application rate, the average maize yield for the 15-year period was related to fertilizer application in the following production function at the bottom of the page.²

The high R^2 of 0,92, implies that outside effects such as the weather were largely isolated. According to the above relationship, if no fertilizer has been applied, the average yield for the 15-year period would be 124 kg per ha. It must be pointed

$$\begin{aligned}
 Y &= 124,13 & + & 9,858 N & + & 13,442 P & + & 3,318 K & + & 261,65 L \\
 & & & (t = 1,38) & & (t = 3,55) & & (t = 12,52) & & (t = 3,46) \\
 & + & 0,0672 PK & + & 1,387 KL & - & 0,1195 N^2 & - & 0,09109 P^2 \\
 & & (t = 3,51) & & (t = 3,62) & & (t = 0,76) & & (t = 2,42) \\
 & & 0,1963 K^2 & & & & & & \\
 & & & - & 29,864 & & & & \\
 & & & & L^2 & & & & \\
 & & (t = 10,88) & & (t = 1,84) & & & &
 \end{aligned}$$

$$R^2 = 0,92)$$

$$df = 0,70$$

where

Y = maize yield in kg per ha

N = LAN in kg N per ha

K = muriate of potash in kg K_2O per ha

P = super phosphate in kg P_2O_5 per ha

L = dolomitic lime in tons per ha

out that the land allocated to the experiments had been in a virgin state with no natural nutrients.

By equating the marginal cost of each nutrient to the marginal revenue of the product, the 15-year optimum application rates of fertilizer were calculated as follows; 23,4 kg N per ha, 97,4 kg P_2O_5 per ha, 118,0 kg K_2O per ha and 6,08 tons lime, every five years.³ The economic optimum average yield was determined at 4 173 kg per ha. These results are presented in the first line of Table 1. This optimum allocation represents a long-term economic optimum. The 15-year average yield increased from 124 kg to the optimum of 4 173 kg per ha through the greater use of fertilizer. These results are exceptionally good also in terms of the stability of optimum levels calculated. This is largely because the trials were repeated over a period of 15 years.

It is of interest to study the effect of the weather on the economic optimum of each nutrient. The 15-year period was divided into three periods of five years each. The five years with the highest average yield for the 81 plots were taken as the best five years and the five years with the lowest average yield as the worst five years. By taking the average yield for the 15 years as 100, a weather index for each of the five years was calculated, based on the total maize yield during each of the five-year periods. The best, fair and worst five-year periods had weather indexes of 138,3, 99,0 and 62,8, respectively. In the worst and best five-year periods the weather deviated about 38 per cent from the average level.

Optimum application rates of nutrients for the three five-year periods are presented in Table 1,

TABLE 1 - Optimum fertilizer application rates and optimum maize yield

Period	Optimum N in kg per ha	Optimum P ₂ O ₅ in kg per ha	Optimum K ₂ O in kg per ha	Lime* tons per ha	Weather index %
Average for 15 years	4 173	23,4	97,4	118,0	6,08 100,00
Best 5 years	4 967	37,8	101,2	112,7	6,31 138,3
Middle 5 years	3 972	23,3	93,8	111,6	5,09 99,0
Worst 5 years	3 156	0	98,0	136,9	7,55 62,8
Five years, 1956-1960	4 829	28,7	125,8	120,1	6,24 121,6
Five years, 1961-1965	4 321	0	121,6	133,1	6,17 82,8
Five years, 1966-1970	3 304	34,1	77,6	82,6	5,36 95,6

*Lime applied every five years

columns 2 to 5. Nitrogen had no effect on production in the five worst years (Table 1, column 4), and the highest optimum application (37,8 kg per ha) took place in the five best years. K_2O and lime had the highest optimum application in the five worst years (Table 1, column 4). Thus under

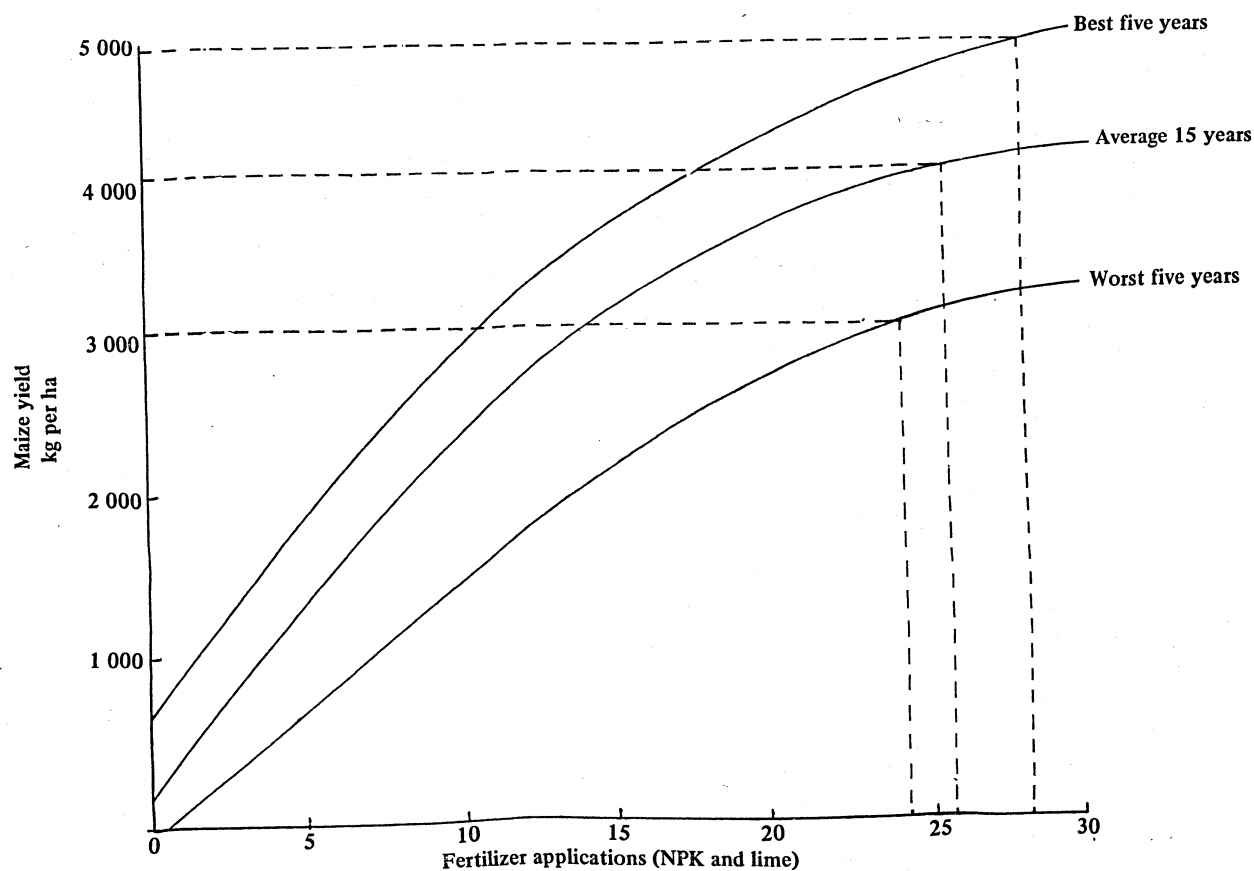


FIG. 1 - Fertilizer/maize response functions, 1956-1970

adverse weather conditions, nitrogen had no effect on yield while larger treatments of K_2O and lime were required.

According to Prof. Orchard, the higher optimum treatment of nitrogen in a good year is partly attributed to the fact that nitrogen was leached from the soil in such a year. The optimum application rate of P_2O_5 did not vary much between the best and worst years. Production functions for the average for the 15 years and the best and worst five-year periods are presented in Fig. 1 and show the varying effect of the weather on the response function.

On the horizontal axis, the four nutrients are combined in a single fertilizer input by assuming that the nutrients were mixed in optimum ratios. Optimum fertilizer mixtures for the three production functions are, however, different. In order to calculate a common input for the three functions, optimum fertilizer mixtures were further weighted by the prices of respective nutrients. Prices of nutrients are used as weighting factors because these prices are also equal to the values of the marginal product of these nutrients at the economic optimum level. The weather shifts the function upwards and to the right or downward and to the left.

The 15-year period was further divided into the first five years, viz 1956 - 60, the second five years 1961 - 65, and the last five years 1966 - 70.

The yields declined over the period; this could be due to better weather conditions during the first five years.

CONCLUSION

Economic optimum nutrient levels varied between the 'good' and the 'poor' years. For example, during 'poor' years nitrogen had no effect on production while the optimum level of K was higher than in a good year.

The 15-year economic optimum production for the standard maize variety was calculated at 4 173 kg per ha. The application rates required for this optimum were 23,4 kg N, 97,4 kg P_2O_5 , 118,0

kg K_2O and 6,08 tons of lime, respectively every five years. Trials with hybrid seed in the same area indicated that the latter's production function is above and to the right of the function of a standard variety. The optimum levels as calculated in this discussion for the standard variety must thus be taken as minimum recommendations. It should also be noted that the optimum yield as calculated for the standard variety, viz. 4 173 kg per ha, is still well above the average maize yield of about 2 000 kg per ha in South Africa.

This analysis is of scientific importance because the trials were repeated over a period of 15 consecutive years. Such repetition was advantageous for the following reasons: (1) The results were statistically significant as measured by R^2 t values and the stability of optimum levels as calculated, and (2) it was also possible to study the effect of the weather and to account for unused fertilizer retained in the soil.

REFERENCES

1. Some nutrients in the trials with hybrid seed were applied at only two levels, which implies a linear relationship with no economic optimum.
2. In this study a quadratic function was chosen because of its desirable properties such as greater flexibility. See Heady, E.O. and Dillon, J.L. 1966. *Agricultural Production Functions*. Iowa State Univ. Press., p.89-91.
3. The optimum nutrient application rate was determined by equating the partial derivative of each element in equation 1 to the corresponding nutrient/maize price ratio. The four equations (four nutrients) were solved simultaneously to determine optimum quantities of N, P, K and L. These quantities were then substituted into equation 1 to calculate the optimum yield. Maize and fertilizer prices obtained in 1974 were used.