FERTILIZATION AND THE EFFICIENT USE OF SOIL WATER

(Met opsomming in Afrikaans)

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Abstract

Many experiments can be cited to prove the favourable influence of the supply of sufficient plantfood on the efficient use of water. The work reported here was planned to study the effect of fertilization on the efficiency of water usage by maize grown in lysimeters under local conditions.
The results show that nitrogen and 'rainfall' treatments had the greatest effect on grain yield. The positive nitrogen response was accompanied by an increased water usage. It was further shown that the amount of dry matter produced per unit of water increased considerably with increased applications of nitrogen.

These results support the findings of other research workers and indicate that an adequate and balanced fertilization programme ensures the efficient utilisation of limited water supplies.

Introduction

With the increasing urban and industrial demands being made on our limited water supplies, the agricultural sector will be pressed to make more efficient use of its decreasing allotment. This situation applies equally to both irrigated and dryland agriculture where farmers will have to eliminate any limiting production factors over which they have control. This means that the available water must be used as efficiently as possible if any contribution towards solving the problems of dwindling water resources is to be made.

In many instances water stress has been a convenient scapegoat to which to attribute any poorly growing crop under dryland conditions. Often the inefficient use of available moisture can be ascribed to inadequate weed control, poor management etc, but in most instances nutrient deficiency is high on the list of accomplices. Although the effect of fertilization on the water-use efficiency of plants has been recognised for many years, its importance and value in this respect has perhaps not been fully appreciated.

In the broadest sense, efficiency in the use of water for crop production infers maximum crop growth and production per unit volume of water used whether that water be actual evapotranspiration, irrigation water applied or rainfall. From the results of a series of classic experiments, Briggs & Shantz (1913) made the following statement:

"Almost without exception the experiments herein cited show a reduction in the water requirement accompanying the use of fertilizers. In highly productive soils this reduction amounts to only a small percentage. In poor soils the water requirement may be reduced one-half or even two-thirds by the addition of fertilizers. Often the high water requirement is due to a deficiency of a single plantfood element. As the supply of such an element approaches exhaustion, the rate of growth as measured by the assimilation of carbon dioxide is greatly reduced but no corresponding change occurs in the transpiration. The result is inevitably a high water requirement."

Since then numerous other workers have studied the relationship between moisture, fertility and crop production and in all cases positive responses to applied fertilizer were accompanied by improved water use. Hilmen *et al* (1961), as reported by Viets (1962), showed that although nitrogen significantly increased the hay yields of forage grasses, total evaporation between fertilized and unfertilized plots was not significantly altered. Nelson (1963) showed that the water required to produce a unit weight of maize decreased by two-thirds when an infertile soil was adequately fertilized. In a similar experiment, Norum (1963) reports an increase of 30 per cent in wheat yields per inch of water used when adequate fertilizer was applied. Many other results, covering a wide variety of crops, may be cited to support the above findings.

When nutrients are deficient, the favourable effects of fertilizers on the mass and distribution of roots leads to a greater vertical and horizontal exploitation and hence more effective utilization of water reserves. Although a very strong response to fertilization may accelerate the withdrawal of moisture, advanced maturity helps compensate for this (Norum, 1963). Studies exploring nutrient-water interactions in plants under varied conditions have gone a long way towards explaining what proper fertilization can mean to crops under great moisture stress.

The work reported in this note, is an attempt to gauge the effect of fertilization on the water-use efficiency of maize grown in lysimeters under local conditions, in order to substantiate the findings of other workers.

Materials and methods

This experiment, conducted at Bapsfontein Research Station by Stiven (1958) was designed to study the effects of nitrogen and phosphate on the uptake of water by maize grown in lysimetres.

The lysimetres consisted of 200 litre (44 gal) drums sunk into the ground, to within a few centimetres of the rim, in two rows. Each drum contained a 1.25 cm sieve which rested on a frame 12 cm from the bottom. A 2.5 cm pipe, extending from the bottom to the top of the drum passed through this sieve to allow free air flow and to enable excess water to be siphoned out. Each drum was filled with soil representative of the locality (Hutton series) and rain was prevented from entering the drums by means of metal covers. The drums were positioned in the centre of a normally planted field of maize.

The experiment was laid out in a randomised block design with 24 treatments replicated twice. Included in each replication were 6 drums left unplanted. Fertilizer treatments and water levels applied were as follows

Nitrogen (kg/ha)	Phosphorus (kg/ha)	Rainfall (mm)
N_0 0	P_0 0	R_1 375
N_1 56	P_1 49	R_2 562
N_2 112		R_3 750
N_3 168		

Each drum was planted to one maize plant (Mic's Success) and fertilizers were given when the plants were 10 cm high. Water was applied according to the average rainfall distribution pattern between September and May for the area.

Height measurements were taken weekly starting immediately after fertilization until maximum height had been attained. All plants grew normally and compared favourably with the surrounding maize. Grain yields and stover weights were recorded at maturity and the amount of water used by a single plant was determined by

(i) the amount of fresh water given to each drum (25 mm equivalent to about 6.2 litres)
(ii) the amount of water siphoned from a planted drum and
(iii) the amount of water siphoned from an unplanted drum.

Results and discussions

(a) Treatment effects

A summary of the statistical analyses of grain yields, stover weights and height measurements is presented in Table 1.

TABLE 1 Summary of the statistical analysis of treatment effects

Source of variation	Linear effects						Cubic effects		
	R	N	P	NR	NP	PR	R	N	P
Grain (g)	xxx*	xx	ns**	ns	ns	ns	ns	xx	ns
Stover (g)	xxx	xxx	ns	xx	ns	ns	ns	x	ns
Heights (cm)	x	ns	ns	ns	ns	ns	ns	ns	ns

*x, xx, xxx Degrees of significance
**ns = Not significant

The results in Table 1 show that the influence of rainfall was greater than any of the other treatments with nitrogen, the next most important source of variation. Phosphorus had no effect on grain yields, stover weights or height measurements. Rainfall significantly increased height but nitrogen did not. The inference here is that the effects of nitrogen are to be found in the grain and stover weights — effects which may not be visibly evident in a field of maize. The rainfall x nitrogen interaction was highly significant in increasing stover weights only and had no effect on height or grain weight. Nitrogen at 168 kg/ha had a slight depressing effect on yield and stover weight (Figure 1).

Grain weights were increased more by the first increment of rainfall than the second, while stover weights increased more rapidly with the second increment than the first. This suggests a near optimum rainfall for grain production and a higher optimum rainfall for stover production.

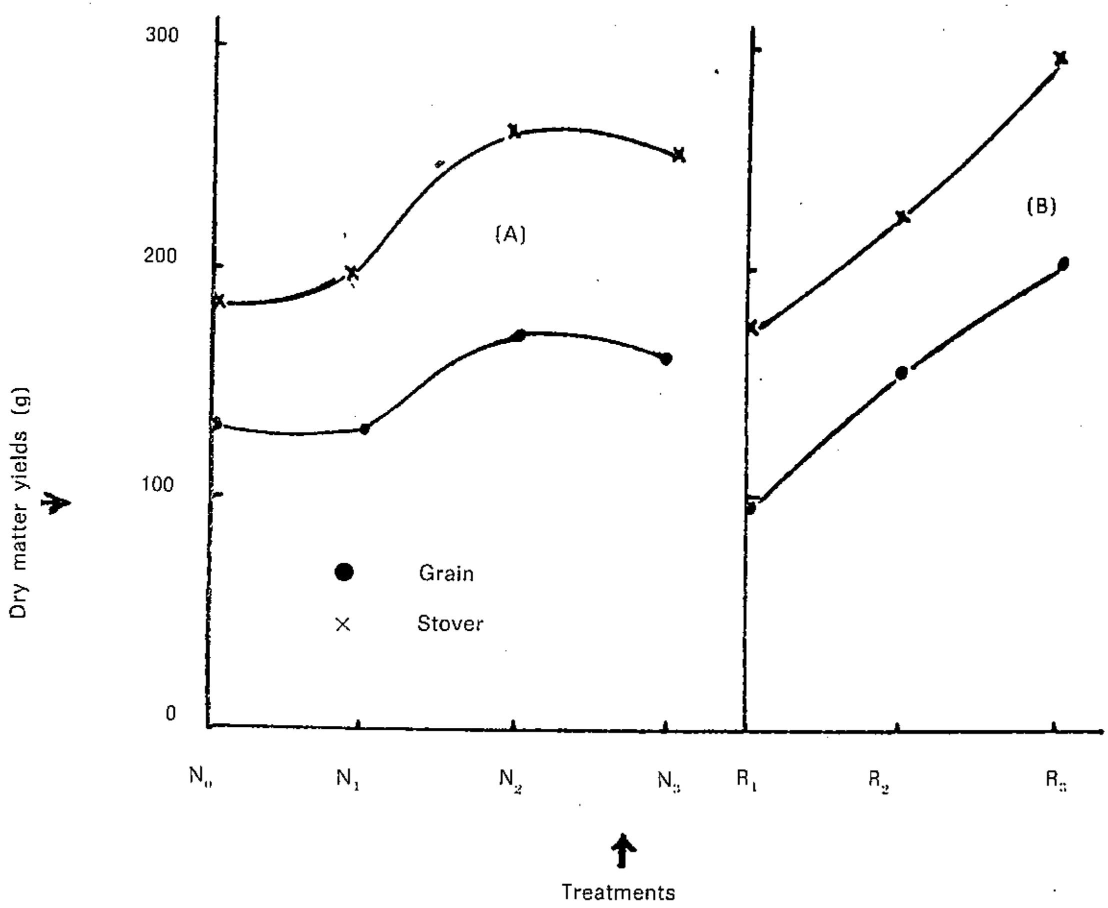

Fig 1 The effect of (A) nitrogen, and (B) rainfall treatments on the grain and stover yields of maize.

(b) Uptake of water

The effect of rainfall and nitrogen treatments on the uptake of water by the plants is shown in Table 2.

TABLE 2 The influence of rainfall and nitrogen treatments on the utilisation of total applied water

Nitrogen treatments	Percentage utilised			
	R_1 (86 litres)	R_2 (130 litres)	R_3 (173 litres)	Average
N_0	13.4	27.1	28.6	23.0
N_1	15.6	26.4	33.9	25.3
N_2	14.2	33.3	37.1	28.4
N_3	17.2	30.7	35.8	27.9

R = Rainfall

Both rainfall and nitrogen treatments had a linear and highly significant (1% level) effect on water uptake while the interaction was significant at the 5% level. From the results in Table 2 it is evident that the maize plants were unable to make very efficient use of the low rainfall although nitrogen did improve water consumption slightly. This effect was more marked up to the N_2 treatment at the higher rainfall applications. The depressing effect of the N_3 treatment on water uptake clearly illustrates the importance of a balanced fertilizer programme. Under these conditions a rainfall of 750 mm was insufficient to justify an application rate of more than 112 kg N/ha. These results nevertheless show that the plants were able to make better use of water in the presence than in the absence of nitrogen.

(c) Water-use efficiency

By calculating the volume of water required to produce a unit weight of dry material, the influence of nitrogen on the actual **water-use efficiency** can be obtained. This data is presented in Table 3.

TABLE 3 Volume of water (litres) required to produce a unit weight (g) of dry material (grain plus stover)

Nitrogen treatments	R_1	R_2	R_3	Average
N_0	0.046	0.095	0.147	0.096
N_1	0.056	0.079	0.182	0.106
N_2	0.044	0.073	0.147	0.088
N_3	0.048	0.066	0.165	0.093
Average	0.049	0.078	0.160	

R = Rainfall

The values in Table 3, averaged over the different rainfall treatments, show that, by increasing the nitrogen application, the quantity of water required to produce a unit weight of dry material, is reduced. This tendency is more clearly shown in the R_2 treatments where, in the absence of nitrogen, 0.095 litres of water was required to produce 1 g of dry material whereas when 168 kg N/ha was applied, this requirement dropped to 0.066 litres. The lack of response at the N_1 level of nitrogen (Figure 1) is probably responsible for the lower observed water-use efficiency at this level.

The results reported above are supported by earlier similar work of Fisher (1957) who studied the influence of nitrogen on the water-use efficiency of maize grown under rainfall conditions varying from 300 mm to continuous saturation.

Discussion

Whether fertilizers increase consumptive use not at all or only slightly, all evidence indicates that water-use efficiency or dry-matter produced per unit of water used can be greatly increased if fertilizers increase yield.

The present data supports these views and illustrates a functional relationship between water-use efficiency and soil fertility. Although data of this nature is applicable under any climatic conditions, more attention should perhaps be given to the higher rainfall regions and irrigated areas where yield potentials are high and water-use efficiency is generally lowest (Tisdale & Nelson, 1966).

In general, any growth factor that increases yield will improve the efficiency of water-use. Included in these factors are variety, plant population, time of planting, pest control and plant nutrient supply. Of all these factors the one most easily controlled, and the most profitable, is soil fertilization. Nevertheless, the cost of the practices necessary to achieve a higher efficiency must also be related to marginal returns in monetary terms. As yield stops short of maximum production so must water-use efficiency, and the importance of optimum balanced fertility must be fully appreciated. Any demand calling for a raising of the productivity of agricultural land can be described as a challenge rather than a problem. By utilizing available water resources at a higher level of efficiency, increased productivity will automatically follow.

Opsomming

BEMESTING EN DIE DOELTREFFENDE GEBRUIK VAN WATER

Talle eksperimente kan gekwoteer word om die voordelige effek van verskaffing van voldoende plantvoedingstowwe op die doeltreffendheid van waterverbruik te bewys. Die werk wat hier gerapporteer word, was beplan om die effek van bemesting op die doeltreffendheid van waterverbruik van mielies, wat onder plaaslike omstandighede in lisimeters gekweek word, te bestudeer.

Die resultate toon dat stikstof- en ,reënval'-behandelings die grootste uitwerking op graanopbrengs gehad het. Die positiewe stikstofreaksie het gepaard gegaan met 'n toenemende waterverbruik. Die gegewens het verder getoon dat die hoeveelheid droë materiaal wat per eenheid water geproduseer is, aansienlik toegeneem het met toename in stikstoftoedienings.

Hierdie resultate ondersteun die bevindings van ander navorsers en dui daarop dat 'n voldoende en gebalanseerde bemestingsprogram die doeltreffende benutting van beperkte watervoorrade sal verseker.

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