Effect of Ferilizer on the Yield of Maize (*Zea mays* L.)

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SUMMARY

The effect of fertilization on the yield of maize was examined on chernoem soil with lime deposits at the experimental station at Látókép of the Center for Agricultural Sciences, University of Debrecen. The yields of maize were evaluated using quadratic regression function, in three years – between 2000 and 2002 – in non-irrigated and irrigated treatments. After calculating the regression equations, by derivation of the functions, we have determined the amount of fertilizers needed for maximum yield.

In the non-irrigated treatments, maximum yield and the active substance amount of fertilizer was as it follows: in 2000, yield of 9,133 t/ha with the application of 384 kg/ha mixed active substance, while in 2002 a yield of 6,289 t/ha with the application 236 kg/ha NPK active substance was achieved. In 2001, due to the favourable precipitation, a yield of 9,864 t/ha was achieved with the application of 245 kg/ha fertilizer. In the case of maximum yield, compared to the unfertilized control, the yield increase was 2,5-5 t/ha. The average increase for 1 kg of NPK fertilizer was 13-19 kg.

We also determined the necessary fertilizer dosage for maximum yield in irrigated treatments. In 2000, 10,003 t/ha with a dosage of 423 kg/ha, in 2001, 11,542 t/ha with a dosage of 277 kg/ha and in 2002, 8,596 t/ha of maximum yield could be achieved with a fertilizer treatment of 277 kg/ha in the examined three years. The yield increase, in irrigated treatments, varied between 3,9-5,9 t/ha so it was greater than in the case of non-irrigated experimetal plots. The yield increase for 1 kg fertilizer varied between 12-21 kg.

INTRODUCTION

We often come across contradictory knowledge regarding the nutrient supply and fertilization of maize. According to Balás (1888): „maize tolerates the greatest possible fertilization and we do not have to be afraid that heavy fertilization will cause any harm".

Cserháti's opinion is very similar: „the more manure we apply, the greater the maize yield will be". In the beginning of maize fertilization experiments in 1955, the basic theory was that maize responds less favourably to greater dosages of fertilizer than other eared plants. According to Grábner (1965): „if we apply manure under maize plants, then fertilization is unnecessary".

Győrffy (1966) stated that maize planted on soil with high cultivation value does not really react to the directly applied manure with extra yield but rather to the nutrient supply level of the soil. Other authors have also stressed that it is more proper to plan fertilization in the framework of the whoile crop rotation (Surányi, 1957; Bauer, 1959; Dezső and Martin, 1965).

Between 1956 and 1960, in the fertilizer experiment of Sarkadi and Bánó, carried out on chernozem meadow soil, the first three years did not result in a significant yield difference between the control yields of the fertilized and unfertilized treatments, while the last two years showed just the opposite effect. It also came to light that in droughty years, fertilization can result in yield depression. However, on soils with poor nutrient supply, a smaller dosage of fertilization resulted in more reliable yields that were less vulnerable to weather.

The long-term fertilizer experiments carried out by Győrffy (1979) characterise the increase of fertilizer optimum quite well with the progress of time. In the case of hybrids cultivated in the 1960's, the appied nitrogen was 80-120 kg and in this range the yield curve palled out. In the 1970's the nitrogen optimum increased to 100-160 kg/ha.

The water supply of a specific area plays an important role in the utilization of fertilzers' active agent especially in the case of nitrogen (Bocz, 1976). Both Hungarian and foreign authors agree that the effect of fertilizers is greatly influenced by weather. Weather influences the heat and moisture supply and has an indirect effect on clay transformation in soils, plant growth, nutrient uptake, quantity of yield and thus on the utilization of manure. (Hank and Frank, 1951; Szász, 1988; Kovács, 1982; Jolánkai, 1982; Nagy, 1988; 1999; 2000; 2001; Ángyán, 1991; Kádár, 1992; Varga-Haszoics and Mikéné-Hegedűs, 1993; Hall et al., 1994).

In the majority of the experiments, medium or good fertilizer effect can be detected in years of high precipitation. In case of severe drought in the first half of the vegetative season, the plant develops well, but in the second half of the vegetative season, due to the great leaf surface index and the increased water demand, a severe water deficiency occurs, which will result in a significant yield depression (Debreczeni and Debreczeniné, 1983; Ruzsányi, 1992; Berzsenyi, 1993; Nagy et al., 1999).

The amount of precipitation and the moisture resources of the soil significantly modify fertilizer need and fertilizer effect. In the case of optimum water supply, fertilizer effect increases but when it reaches the level of harmful water surplus, the effect of fertilizers decreases (Harmati, 1987). The influence of soil characteristics depends on the soil fertility, the thickness of the cultivation layer and the water balance (Sarkadi, 1975; Búzás, 1987; Németh and Búzás, 1991; Ruzsányi, 1992). Optimum nitrogen supply contributes significantly to the number of grains per maize cob, less significantly to the increase of kernel weight (Bocz and Nagy, 1981).

In cases of nitrogen deficiency, the accumulation of dry matter and the dynamics of dry matter accumulation are slower (Debreczeniné and Szlovák, 1985; Hanway and Russel, 1969; Berzsenyi, 1993). Good nutrient supply promotes the fast, early increase of the leaf surface index of maize and, for this reason, the optimum LAI value can be maintained longer, which is favourable for the endurance of biomass and the flow of assimilates into the grain yield (Anderson et al., 1985; Berzsenyi, 1993). In cases of drought, this favourable characteristic comes with an economic benefit, because maize is deprived of water in the early phase of the vegetative season, which reaches its peak in the reproductive season and thus decreases the yield.

The method and degree of fertilization should be determined not on the basis of the different maximum yield, but rather on the basis of profitability (Irvine, 1963; Mejendorf, 1971). The upper limit of fertilizer use has to determined on the level economic optimum arising from extra yield (Debreczeni, 1980).

MATERIALS AND METHOD

The Center for Agricultural Sciences of Debrecen University in cooperation with KITE (Maize and Industrial Crop Production Cooperation) of Nádudvar, a three factorial (fertilizer, irrigation and genotype) experiment was started. The experiment is carried out on chernozem soil with lime deposits, where we examined the productivity, natural nutrient utilizing ability, fertilizer requirement and utilization of ten maize hybrids annually.

The fertilizer treatments: 1 N : 0,75 P_2O_5 : 0,88 K_2O constant ratio NPK dosage experiment, where the basic dosage is 79 kg/ha – from which N 30 kg/ha – and we applied 1, 2, 3, 4, 5 times the dosage along with an unfertilized control. Identical NPK ratio dosages were simply indicated with the amount of nitrogen during the evaluation. We applied the amount of irrigation close to the water demand of the irrigated plant.

We used the De 377 hybrid in our research. The experiment was setup in rows of four repetitions. Within one repetition, we used the same plant density with six fertilizer treatments and ten hybrids in random order, in irrigated and non-irrigated versions. The size of the repetition was 1260 m^2, the fertilized parcels were 210 m^2. The total number of parcels were 6 treatments x 10 hybrid = 60 x 4 repetitions = 240 x 2 (irrigation) = 480.

Soil charactersitics: The soil of the experimental station is lowland calcareous chernozem formed on loess. The nitrogen and phosphorous supply of the soil is medium. Its potassium content is high (humus content 2,8-3%, total N 0,14-0,18%, AL-P_2O_5 130-200 mg/kg, AL-K_2O 240-280 mg/kg). The thickness of humus layer is 70-90 cm. The pH (KCl) value is 6,2, soil plasticity (KA) is 43. Microelement deficiency cannot be detected. The groundwater level is between 6-8 meters. The VKmin value of soil is 27-29 tf %. The 0-100 cm soil profile can store 275 mm, while the 100-200 cm stores 265 mm of moisture. The available VK at 0-100 cm is 157 mm, at 100-200 cm is 150 mm.

Weather characteristics: In the examined period, the precipitation for maize was unfavourable. All three years were dry. In 2001 and 2002, drought occured in spring of both years. In 2000 a severe drought was experienced.

Data obtained during the experiment was evaluated with correlation and regression analysis (Sváb, 1981; John, 1971; Winer, 1971; Drimba and Ertsey, 2003; Drimba et al., 2000; Ertsey and Drimba, 1995). The applied fertilizer, irrigated treatments and setup were considered during the preparation of the analysis, using the yields in the average of ten maize hybrids.

During the regression analysis, we used a quadratic function. We minimized the square sums of the deviations. In order to determine if the analysis was good, we considered the multiple R value, the result of the F probe and the average amplitude of the square residual MQ (Huzsvai, 1994). The parameters of the function were tested with a t-probe.

The evaluation was done with the help of an IBM compatible computer and the SPSS software.

RESULTS

The effect of fertilization on yield was evaluated with the help of regression in irrigated and non-irrigated forms, in the average of three years and anually for the years of the 2000-2002 period, on the basis of dosage experiment setup on the Látókép experimental farm of the University of Debrecen, Center for Agricultural Sciences. During our calculations we applied deviation calculations and characterised natural nutrient utilization on this baisi.

We checked whether the function was correct along with multiple R-value with the variance analysis of the regression, with F probe and its accuracy by determining the standard error of the estimate. The correctness of the equation's parameters was checked with the help of a t-probe, and applied a bilateral symmetrical test to consider significance.

Following the calculations of regression equations, we carried out the derivation of functions and, with this figure, we determined the quantity of fertilizer dosage.

2000 was a dry year. In the growing season, 180 mm less precipitation fell than in the average of 50 years (340 mm), in the winter period however more precipitation fell than in average years. In the case of all fertilizer scales, the yield of the De 377 hybrid – both in the irrigated and unirrigated treatments – was average. The maximum yield was 10,003 t/ha, which was achived with the application 277 kg NPK mixed active compound.

Precipitation in 2001 was average, or slightly higher than average. This period was more favourable for maize than the previous year, precipitation that fell during the growing season met the average of 50 years. In the precipitation data of the winter term, significant deviation appeared, about twice as much precipitation fell between the harvest of pre-sowing and sowing than in the same term of the previous year. The maximum yield was 11,542 t/ha, which was achieved with the application of 277 kg of mixed NPK active compound.

In 2002, the growing season was dry. A 100 mm less precipitation fell, than the average of 50 years. This mainly affected the first half of the growing season, and accordingly it had great effect on the yields. The precipitation of the winter term was average, this influenced the great precipitation deficiency favourably. The maximum yield was 8,596 t/ha, which was achieved with the application of 287 kg of fertilizer active compound (*Table 1*).

Table 1

The effect of fertilization on the yield of maize

Active compound of fertilizer kg/ha	Unirrigated			
	2000	2001	2002	Average
Control	4,16	5,16	3,9	4,41
1	5,99	7,58	4,89	6,15
2	7,56	9,30	5,81	7,56
3	8,20	10,26	6,68	8,38
4	9,13	9,01	6,00	8,05
5	9,08	8,22	5,01	7,44
Average	8,37	8,25	5,38	7,33
	Irrigated			
Control	6,01	5,99	5,01	5,67
1	7,79	7,97	6,17	7,31
2	9,12	10,45	7,41	8,99
3	9,64	11,97	9,01	10,21
4	10,19	11,29	8,80	10,09
5	10,73	10,37	7,76	9,62
Average	8,91	9,67	7,36	8,65

1=30 kg N+22,5 kg P_2O_5+27,5 K_2O; 2=60 kg N+45 kg P_2O_5+53 K_2O; 3=90 kg N+67,5 kg P_2O_5+70,5 K_2O; 4=120 kg N+90 kg P_2O_5+98 K_2O; 5=150 kg N+112,5 kg P_2O_5+125,5 K_2O

The validation of fertilization in the unirrigated treatments

The results of the statistical evaluation regarding unirrigated treatments are shown in *Table 2-4*. On the basis of statistical evaluation of unirrigated treatments, the multiple R-values were between 0,80-0,92 during the three years, which on the basis of the F-probe were proved to be significant under the level of 0,1% with the help of an unilateral test. The parameters of the equation, both the linear and the squared term were significant under the level of 0,1% on the basis of a t-probe.

During the three years, the average error of the estimate was between 600-900 kg/ha. We have carried out in all three years, the series correlation of residual values. Their values fluctuated between 0,07-0,17. We determined that the accuracy of our estimate did not depend on the magnitude of the yield average.

On the basis of the collective evaluation of the three years, we got the highest yield, 9,864 t/ha with the application of 245 kg of NPK mixed active compound.

Table 2

The statistical result of the De 377 maize hybrid, unirrigated, Debrecen, 2000

The source of variance	SQ	FG	MQ	F-value	Significance level
Regression	75,494223	2	97,747111	58,41827	0,0000
Residue	13,569203	21			
Independent variables	**Regression coefficient**	**Error of the coefficient**	**Standardized regression coefficient**	**t-value**	**Significance level**
Fertilizer	0,025861	0,004316	1,811921	5,3992	0,0000
Fertilizer2	-0,0003364	0,000010464	-0,972288	-3,215	0,0042
Constant	4,163266	0,364779		11,413	0,0000

Table 3

The statistical result of the De 377 maize hybrid, unirrigated, Debrecen, 2001

The source of variance	SQ	FG	MQ	F-value	Significance level
Regression	61,095322	2	30,547661	45,02057	0,0000
Residue	14,249063	21	0,678527		
Independent variables	**Regression coefficient**	**Error of the coefficient**	**Standardized regression coefficient**	**t-value**	**Significance level**
Fertilizer	0,038737	0,004423	2,950822	8,759	0,0000
Fertilizer2	-0,000079089	0,000010723	-2,484884	-7,376	0,0000
Constant	5,120599	0,373806		13,699	0,0000

Table 4

The statistical result of the De 377 maize hybrid, unirrigated, Debrecen, 2002

The source of variance	SQ	FG	MQ	F-value	Significance level
Regression	44,384815	2	22,192408	30,47543	0,0000
Residue	15,292337	21	0,728207		
Independent variables	**Regression coefficient**	**Error of the coefficient**	**Standardized regression coefficient**	**t-value**	**Significance level**
Fertilizer	0,027223	0,004582	2,330085	5,942	0,0000
Fertilizer2	-0,000047483	0,000011109	-1,676289	-4,274	0,0003
Constant	4,694414	0,387248		12,122	0,0000

With the help of the function's derivates, we determined the quantity of NPK fertilizer active compound which, in 2000 with a dosage of 384 kg/ha fertilizer active compound resulted in 9,133 t/ha, in 2001 with a dosage of 245 kg/ha NPK dosage resulted in 9,864 t/ha, and in 2002 with a dosage of 236 kg/ha resulting in 6,289 t/ha maximum yield.

The evaluation of fertilization effect in irrigated treatments

The results of statistical evaluation in irrigated treatments are shown in *Table 5-7*. The multiple R values were between 0,86-0,95 during the three years. According to the F-probe, fertilization and the yield of maize show a strong correlation under the level of 0,1% significance in all three years. The approximation with a quadratic function varied between 0,8-1,2 t/ha. The t-probes proved the significance of linear and squared members at less than 0,1%. The differences between the estimated and observed yield averages are independent, they do not depend on the quantity of the yield.

With the help of the function's derivates, we determined the quantity of NPK fertilizer active compound which, in 2000, with a dosage of 423 kg/ha fertilizer active compound, resulted in 10,003 t/ha, in 2001 with a dosage 277 kg/ha NPK dosage resulted in 11,542 t/ha, and in 2002 with a dosage of 287 kg/ha resulted in 8,596 t/ha maximum yield.

Examining the slope of the quadratic function, we can determine that we get a great yield at relatively low nutrient levels. It follows that, the slope is moderate and around the yield maximum a longer constant section can be observed. In this section the quantity of yield barely changed. The slope of the quadratic function is so small in this function that with the decrease of fertilizer belonging to maximum yield, the quantity of the yield decreases only on a small scale. This means that even with lower levels of fertilization, we get almost maximum yield and this is a very important result from a practical point of view.

Table 5

The statistical result of the De 377 maize hybrid, irrigated, Debrecen, 2000

The source of variance	SQ	FG	MQ	F-value	Significance level
Regression	70,116186	2	35,058093	102,05615	0,0000
Residue	7,213872	21	0,343518		
Independent variables	**Regression coefficient**	**Error of the coefficient**	**Standardized regression coefficient**	**t-value**	**Significance level**
Fertilizer	0,023026	0,003147	1,731315	7,317	0,0000
Fertilizer2	-0,000027194	0,0000076299	-0,843355	-3,564	0,0018
Constant	5,128675	0,265973		19,283	0,0000

Table 6

The statistical result of the De 377 maize hybrid, irrigated, Debrecen, 2001

The source of variance	SQ	FG	MQ	F-value	Significance level
Regression	98,696295	2	49,348147	54,87805	0,0000
Residue	18,883891	21	0,899233		
Independent variables	**Regression coefficient**	**Error of the coefficient**	**Standardized regression coefficient**	**t-value**	**Significance level**
Fertilizer	0,042480	0,005092	2,590354	8,343	0,0000
Fertilizer2	-0,000076793	0,000012345	-1,931371	-6,221	0,0000
Constant	5,667770	0,430327		13,171	0,0000

Table 7

The statistical result of the De 377 maize hybrid, irrigated, Debrecen, 2002

The source of variance	SQ	FG	MQ	F-value	Significance Level
Regression	44,384815	2	22,192408	30,47543	0,0000
Residue	15,292337	21	0,728207		
Independent variables	**Regression coefficient**	**Error of the coefficient**	**Standardized regression coefficient**	**t-value**	**Significance Level**
Fertilizer	0,027223	0,004582	2,330085	5,942	0,0000
Fertilizer2	-0,000047483	0,000011109	-1,676289	-4,274	0,0003
Constant	4,694414	0,387248		12,122	0,0000

During the examined three years, the maximum total yield was achieved with the application of 277 kg/ha NPK mixed active substance. This fertilizer dosage can be recommended, because in this case the marginal efficiency of fertilization is 21 kg/kg, so it can be considered favourable. In the case of the maximum yield, yield increase compared to the unfertilized treatment varied between 2,6 and 5 t/ha, the average increase for 1 kg fertilizer was 13-19 kg (*Table 8*).

Table 8

Values belonging to maximum yield, Debrecen, 2000-2002

Years	NPKmax.	Yield t/ha	Increase t/ha	Average fertilizer efficiency kg/kg
Non-irrigated				
2000	384	9,133	4,969	13
2001	245	9,864	4,743	19
2002	238	6,289	2,574	11
Average	289	8,43	4,1	14,33
Irrigated				
2000	423	10,003	4,874	12
2001	277	11,542	5,875	21
2002	287	8,596	3,902	14
Average	329	10,047	4,88	15,67

In the case of the irrigated treatments, the yield increasing effect of fertilization was greater than in unirrigated treatments. Greater yield, however, does not always mean greater fertilizer dosages. About the marginal efficiency of fertilization, we can say that usually – excluding the year 2000 – the marginal efficiency of the irrigated treatments is higher than that of the unirrigated treatments (*Table 9*).

The quantity of the economic fertilizer dosage always depends on the economic environment. In order to determine the quantity of the economical fertilizer dosage – by using the data of the experiment – we determined the fertilizer active compound quantities belonging to 15 kg grain yield, so these values can be benchmarked to different economic conditions quite well. We carried out the evaluation for both unirrigated and irrigated parcels. In the case of irrigated treatments, the marginal efficiency of fertilization was 10 kg/kg in 2001, so in this case the value of boundary productivity is -5, so it is worth increasing the quantity of fertilization, while in the irrigated treatment this unfavourable situation arose in 2000.

Table 9

The average efficiency of fertilization

Years	Marginal efficiency 15 kg/kg fertilizer	Yield t/ha	Increase t/ha	Average fertilizer efficiency kg/kg
Non-irrigated				
2000	161	7,461	3,297	20
2001	150	9,153	4,032	27
2002	74	5,073	1,358	18
Average	128,33	7,229	2,896	21,67
Irrigated				
2000	148	7,934	2,805	19
2001	179	10,81	5,142	29
2002	129	7,412	2,717	21
Average	152	8,72	3,56	23

In conclusion on sites similar to the experimental location, 236-384 kg/ha mixed active compound without irrigation can be recommended while in irrigated treatments, an application of 277-423 kg/ha NPK active compound may be used, in the case of the De 377 hybrid.

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