EVALUATION OF THE INTERACTION BETWEEN NUTRITIVE SUPPLY AND WATER MANAGEMENT ON THE BASIS OF A LONG-TERM EXPERIMENT IN DEBRECEN

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The high degree of climate variability is one of the highest risk factors of production, which has to be taken into consideration at all times even within the framework of modern agriculture.

One of the most important opportunities of adapting to changing climatic conditions is the evaluation of plant types and genotypes according to fertility and genotypes.

The effect of year on the yield of maize was examined through using a twenty-four year yield sequence. Weather was changeable in the examined period, therefore the effect of fertilisation was very different as well. The relationship between the quantity of precipitation in the winter period and growing season and the unfertilised treatments can be easily detected. The quantitative relationship between the two variables is average, because besides the total quantity of the precipitation, the periodical distribution is also a significant factor that influences yield. Significantly small yield is not always accompanied by the lowest amount of precipitation (1994, 1995). Larger yields however, were always accompanied by higher precipitation (1980, 1998, 1999, 2001, 2004, 2005, 2008). It can be well detected that with similar precipitation quantities, different amounts of yields will form due to the periodical distribution of changing precipitation. The accessible spring water resource of the soil profile is decisively influenced by the precipitation of the winter period. Based on the evaluation of our research results we have found that the specific years showed a close correlation with fertilisation. In droughty years or in years with lower, average, or higher than average precipitation, the application of higher fertiliser dosages was more favourable. The application of not more than 60 kg N ha^{-1} fertiliser dosage is recommended in droughty conditions and especially in consecutive dry years. A higher fertiliser dosage (1995) increases the risk of maize production, thus reducing the efficiency of maize production. In the case of favourable water supply – based on experiment results – the application of 120 kg N ha^{-1} fertiliser dosage is justified. According to the results of variance analysis, the examined fertiliser effect is significant when jointly examining the twenty-four years. When evaluating the specific years separately, we found that the effect was different, depending on the degree of water supply.

The yield level of maize hybrids was 10 t ha^{-1} in years with favourable water cycles, while in drought years, the harvestable yield was 2–4 t ha^{-1}. Yield fluctuation can be reduced through appropriate soil cultivation, water and nutrient supply.

Key words: maize, fertilisation, crop year

Introduction

The high variability of climate is one of the biggest risk factors of production and producers have to continuously consider this factor in modern agriculture. In the last one hundred years, the proportion of drought and extremely wet years significantly increased. Both have a negative effect on field crop production and its predictability. *Barrov et al.* (2000) concluded to a similar tendency also in Europe, when they determined the change of the quantity of precipitation in the winter (+0,4–+3,6%) and summer (-0,5–+3,7%) periods between 1961-1990. *Berényi* (1956) stated that the quantity of precipitation is of significant importance. He established that natural water supply determined yield in a 55-75% proportion. *Láng* (1976) and *Márton* (2002) also proved the significant effect of weather on yield. Many researchers found close correlation between ”crop year effect”, the nutritive supply of crops and yield (*Kádár* 1992, *Tóth et al.* 2002, *Nagy* 2008). *Berzsenyi* and *Győrffy* (1997) stated that lower fertilisation doses have higher stability in dry years, whereas higher doses are more stable in wet years.

Material and methods

We carried out the measurements at the Látókép experiment site of the University of Debrecen, Center of Agricultural Sciences and Engineering on mid-heavy calcareous chernozem soil in a multifactoral long-term field experiment between 1980–2008.

Fertiliser treatments: The NPK dose experiment had a constant ratio of 1 N:0,75 P2O5:0,88 K2O, the basic dose was 80 kg ha-1 – of which the amount of N was 30 kg ha-1 –, and we used treatments of 1, 2, 3, 4 and 5 times the basic dose, plus a control treatment without fertilisation. The experiment had a strip plot design, with the hybrid and fertiliser treatments located crosswise in four replications.

Air temperature (°C) and relative humidity (%) were logged at heights of 0.5, 1 and 2 m, soil temperature (°C) at depths of 50, 250 and 500 mm, incoming radiation (W/m^2) and the amount of precipitation (mm) were measured continuously by an automatic measurement and data-logging station.

Evaluation method: We used SPSS for Windows 13.0 statistical software package for evaluation. We used the general linear model (GLM) to express the effect of treatments on yield. During the calculation, we determined sum of squares using Yates' method. In order to compare the treatment mean values, we determined the 5% significant difference ($LSD_{5\%}$) and we created homogeneous groups using multiple mean value comparison tests (Duncan's method). During the multiple comparison, we correct the confidence intervals using Bonferroni's method to avoid the accumulation of alpha error. The yields in the homogeneous group do not differ from each other on a 5% level of significance.

Results and conclusions

We examined the effect of crop year on yield using a 24-year long yield series. The control plots of the long-term experiment – that have not been fertilised for 25 years – provided a reliable basis for comparison.

During the examined period, the weather was rather various, therefore, the effect of fertilisation is different as well (Figure 1). The correlation between the total amount of precipitation in the winter period and the growing season and the yields of the non-fertilised treatments can be easily seen. There is an average quantitative relationship between the two variable, because the temporal distribution of precipitation is also a significant yield modification factor, besides its total amount.

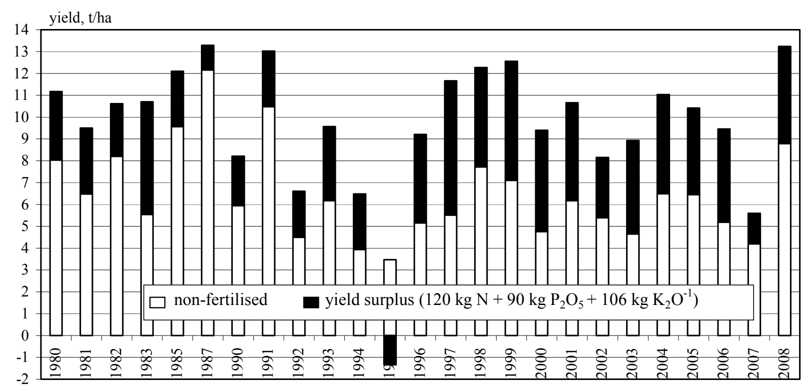

Figure 1. The effect of crop year and fertilisation on the yield of maize hybrids (Debrecen, 1980–2008)

Remarkably low yields are not always associated with the lowest amounts of precipitation (1994, 1995). Nevertheless, higher yields were only obtained in times of high amounts of precipitation (1980, 1998, 1999, 2001, 2004, 2005, 2008). It can be observed that different yields are formed in the case of similar amounts of precipitation, due to the different temporal distributions. The useful spring water stock of the soil profile is significantly affected by the amount of precipitation during the winter.

The amount of precipitation in the growing season of 1991 was only 44 mm lower than the many years' average. As a result of the favourable weather for maize, the crop population had an outstanding yield in the average of treatments (12.446 t ha^{-1}). During the examined 24 years, this was the one when we obtained the highest yield (13.019 t ha^{-1}) in the 120 kg N ha^{-1} fertiliser treatment.

In the growing season of 1992, the amount of precipitation was by nearly 162 mm less than the 30 years average. The situation was further worsened by the rather low, 173 mm precipitation of the winter period. The average yield was 5.824 t ha^{-1}.

In 1994, the precipitation in the winter period was average, but it was 105 mm less in the growing period in comparison with the 30 years average. May, June and July were especially dry months, the amount of precipitation was only 13 mm in July. These unfavourable conditions caused the low yield (5.563 t ha^{-1}) in the average of treatments.

Among the years in our examination, the most unfavourable weather was observed in 1995. The amount of precipitation of the winter period was by 70 mm lower than the average value, and there was only 3 mm rain in the growing period from the end of June until the beginning of August, which had been unprecedented before. The extraordinary water shortage, accompanied by the hot days whose maximum temperature was permanently more than 30 °C caused yield depression in the fertilised treatments (Figure 1). The drought which appeared in the critical phenologycal phase of maize basically destroyed yield. Yield was only 2.212 t ha^{-1}.

In 1998, there was a dry winter, but the growing period was wet and the amount of precipitation was by nearly 130 mm more than many years' average. During all critical months (May, June, July), there were more precipitation which is also shown by the average yield (10.826 t ha^{-1}).

The weather of the two last years was also completely different. The extreme weather of 2007 established extreme production circumstances for maize. In July, several day long 40 °C heat strongly damaged maize. The heat was accompanied by a long precipitation shortage, too. The mean temperature was higher than many years' average for one whole year (without a break) between September 2006 and August 2007. The effect of the drought year was also presented in the average yield (5.369 t ha^{-1}).

The weather in May 2008 affected vegetative growth to a lesser extent, due to the water stock, whereas low temperature had a greater influence on it. The period from June to harvest provided optimal environmental and weather conditions for the development of maize populations. The favourable, nearly optimal weather conditions made it possible to obtain outstanding yields (11.763 t ha^{-1}).

Based on the evaluation of our research results, we concluded that crop years had a close correlation with precipitation, which can be well characterised by the grain yield per 1 mm precipitation (Figures 2–3). In drought years, smaller fertiliser doses were more favourable, whereas higher doses had a better effect in years with average or more than average precipitation. Within circumstances inclined to drought, but especially in several subsequent dry years, lower fertiliser doses (not more than 60 kg N ha^{-1}) is advised. Applying higher fertiliser doses (1995) increase the risk of maize production, thereby reducing the success of production. In the case of favourable water supply – based on the experiment results – the application of 120 kg N ha^{-1} fertiliser dose is justified.

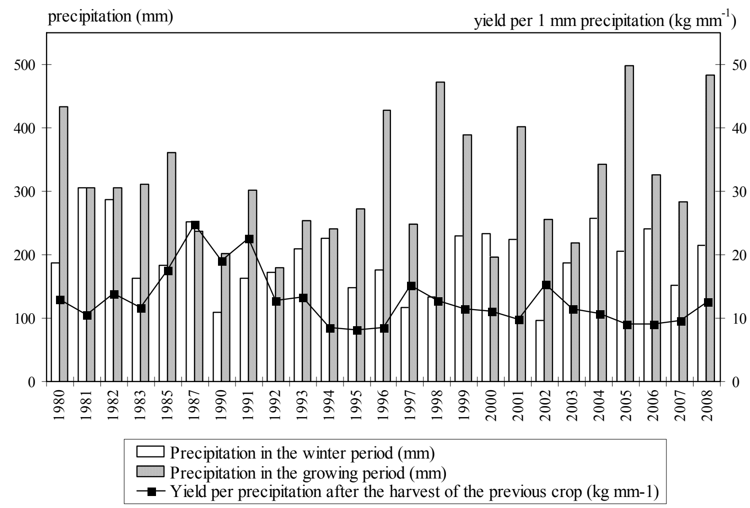

Figure 2. Grain maize yield per 1 mm precipitation, non-fertilised treatments (Debrecen, 1980–2008)

When we compare the effects of factors in the examined years, we can establish that on the basis of Mean Square (MS) values, year has the most significant (MS=1116,5; P<0,001) effect. Due to the results of the variance analysis, the effect of fertilisation is significant (MS=676,7, P<0,001) when we consider all 24 examined years together. When analysing each crop year separately, we can conclude that the effect was different, depending on the amount of water supply. The yield surplus of fertilisation was 3.046 t ha^{-1} in the average of the 24 years. Yield results were higher than average in 1981, 1983, 1996–2001, 2003–2006 and 2008. The biggest fertiliser effect (5.226 t ha^{-1}) was measured in 1983. Maize hybrids utilised natural nutrients weakly in 1992, 1994, 1995, 2000 and 2003, whereas they utilised them in perfectly in 1980, 1982, 1985, 1991 and 2008.

In crop years with favourable water cycle, the yeidl level of maize hybrids were 10 t ha^{-1}, whereas it was 2–4 t ha^{-1} in drought years. Yield fluctuation can be reduced by adequate cultivation, water and nutrient supply.

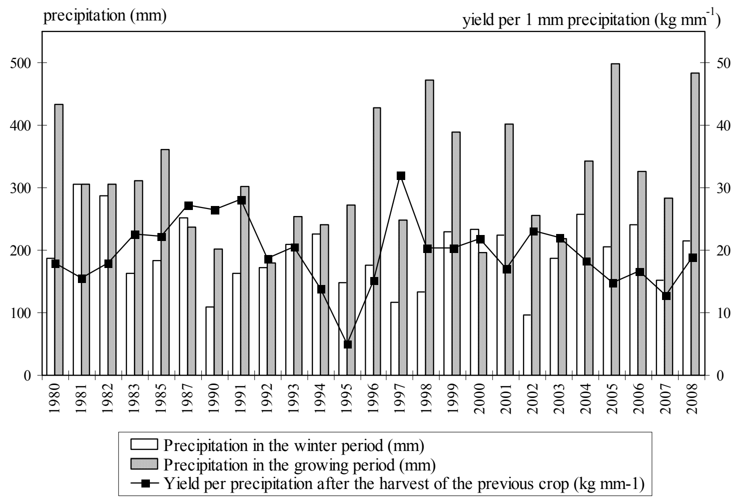

Figure 3. Maize grain yield per 1 mm precipitation, 120kg N+ 90kg P_2O_5+106kg K_2O ha^{-1} (Debrecen, 1980–2008)

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