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THE EFFECT OF FOLIAR APPLICATION OF DIFFERENT FERTILIZERS ON TECHNOLOGICAL AND ECONOMICAL PARAMETERS OF CORN

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Abstract

Many agro-technical factors are of great importance concerning the amount of crop in corn production. One of these factors is nutrient supply. Plants are supplied with macro-, meso – and microelements. Nowadays cultivated plants cannot always obtain enough microelements from the soil, therefore the importance of foliar fertilization increased. Applied at the right time, foliar fertilization might increase the resistance of corn against biotic and abiotic factors as well. In the experiment the authors examined the effect of three foliar fertilizer products and their combinations on the important elements of the crop development of corn, and their application from economic point of view. The experiment was set in three repeats in random blocks on meadow soil in 2015. The nitrogen supply of the soil is good, the phosphorus and potassium supply is very good, however the zinc content of the soil is low. The corn yield without foliar fertilisation was 6.39 t/ha. The highest yields were achieved after the following treatments: Amalgerol + Fitohorm Turbo Zn (7.50 t/ha), Fitohorm Turbo Zn (7.35 t/ha), and Algafix + Fitohorm Turbo Zn (6.94 t/ha). Treatments with products containing Zn resulted in the best amounts of yields indicating that the low Zn levels of the soil in this area might hinder a higher corn yield. The Zn uptake might be hindered by the too much phosphorus in the soil because of the antagonism between the two elements. As for the generative factors, the results of the treatments with Algafix and Fitohorm Turbo Zn were the best. Based on the economic evaluation, it was the

experiment with Fitohorm Turbo Zn treatment that provided the highest profit (24,455 HUF/ha). In addition, applying Algafix treatment turned out to be also profitable (470 HUF/ha).

The results of the test concern the conditions of the experimental area. As for other areas, soil tests and, where possible, plant tests should be made to select the best available foliar fertilizer products.

Key words: Zea, mays L., micronutrients, grain yield, thousand grain weight, shelling rate, zinc

INTRODUCTION

Corn is one of the plants grown on the largest areas in the world and in Hungary as well. Its production is vital since it is a kind of grain that can be used in many ways. The genetic productivity of the newest corn hybrids is continuously growing. In order that the potential of hybrids productive capacity can be utilized as much as possible, the harmony of the agro-technical factors is necessary (Kovács *et al.* 2016).

The nutrient supply is one of the production factors, which plays a significant role in shaping the size of the crop. To provide an efficient nutrient supply, the necessary nutrients should be dispensed in accordance with plant requirements. In addition to the primary nutrients, plants also need meso – and microelements. These latter are required in relatively small amounts, however several factors might hamper them to be taken up from the soil. In order to obtain a more effective uptake of the latter, foliar fertilisation is applied, which is an effective method of supplementing meso – and microelements. The utilisation is also better with this method, because there are no losses like in the uptake of nutrients through soil. (Hoffmann *et al.* 2014, Rátonyi *et al.* 2014).

The authors wanted to know what effect the various foliar fertilizer formulations and combinations have on corn yield, and which treatments and treatment combinations bring economic benefits.

The supply of nutrients is effective, economical and environment-protective when the expertise and harmony of all production technology elements are provided (Nagy 2007). Fertilisation is an important agro-technical factor, which can help moderate the quality and quantity anomalies between the various production years and production areas (Árendás 2006, Pepó 2006, Dóka *et al.* 2007, 2014, Pepó *et al* 2016, Futó *et al* 2015). The low yield averages in corn production can be due to the fall-back of chemical fertilisation; this is why the use of fertilisers must be increased in order to reach higher and more consistent amounts of crop (Popp 2000, Komarek 2007a, 2007b, 2007c, 2008).

In practice, foliar fertilisers are able to meet only a few percent of the main macroelement demands of plants. Foliar fertilisation cannot provide nutrient uptake through the soil, just supplements it. The foliar fertiliser can get directly to the place of use, the leaf cells and can act immediately without the mediation of the soil. Nutrient uptake can be sustained even in drought, with little water. Under ideal conditions, the nutrient utilisation might reach 100% (Kádár 2002).

Foliar fertilisation can only be effective if the missing nutrient elements are replaced indeed in the right way at the right time. Foliar fertilisation tests and experiments must be conducted to check the effect of the substances (Kádár 2008).

Today, cultivated plants cannot always get enough microelements from the soil to achieve high yields, therefore the significance of foliar fertilization increases. Timing is vital, as crop losses or loss of quality can be avoided by rapid and effective intervention. However, with the use of foliar fertilisers, and under favourable conditions, yield increase and quality improvement can be reached as well. With foliar fertilisation carried out at the right time the resistance to environmental stress factors, pathogens and pests can be increased. Corn is sensitive to zinc deficiency. On large areas of plough land there is not enough zinc for the plant. In the absence of zinc the growth of the corn is restrained, the generative organs are damaged, the flower-forming is delayed, or perhaps it will not happen at all. The soil examination results show that due to the intensive production the zinc supply fell back sharply on the good-endowed corn growing districts of Hungary (Hoffmann *et al.* 2014). Relative zinc deficiency can occur even when there is a good supply of zinc in the soil, which can be caused by the antagonism of phosphorus and zinc uptake in the areas where there are good or very good (sometimes too much) phosphorus supplies (Hoffmann *et al.* 2014, Kincses *et al.* 2002, 2005).

Foliar fertiliser products might be suitable to improve the crop-forming elements and the amount of the yield. When applying these fertilisers, yield stability can be increased and they might affect the nutrient parameters as well (Jakab *et al.* 2014a, 2014b, 2016).

The aim of the study to determine how different foliar fertilizers and their combinations is authors wanted to know what affect corn yield; furthermore, which treatments and treatment combinations bring economic benefits.

MATERIAL AND METHODS

Weather and soil characteristics

The experiments were set on the area of Tangazdaság Ltd. in Hódmezővásárhely. The soil was meadow with good nitrogen and very good phosphorus and potassium contents. However, the Zn content, which is the most important microelement for corn, was low (Table 1).

Table 1. Main soil properties of the experimental field

pH (KCL)	$CaCO_3$ (%)	P_2O_5 (mg/kg)	K_2O (mg/kg)	Zn (mg/kg)	Humus (%)	K_A
7.17	3.33	336	620	1.76	3.39	48

Source: Bácskalabor Ltd. (2015)

The year 2015 was unfavourable for corn production. In April, May and September the amount of precipitation was lower than the long term average. The low amount of rainfall in June was especially unfavourable for corn since the flowering of the plants started at that time. The lack of precipitation in September did not affect the development of the plants as they became fully mature by then. Considering the whole vegetative period, the rainfall deficit was 83.6 mm, which is a considerable value. The average temperature exceeded the 50-year average in each month of the vegetation period of corn. In July and August particularly high positive deviations compared to the long-term average were observed (1.9^{0}C and 2.8^{0}C) (Table 2). The positive deviation of average temperature together with rainfall deficit had a negative effect on the development of corn, which resulted in low yields.

Table 2. Precipitation and temperature in the vegetation period of corn in Hódmezővásárhely (2015)

Months	Apr.	May	June	July	Aug.	Sept.	Total / Average
Precipitation 2015 (mm)	7.6	75.5	12.2	61.6	51.8	29.0	237.7
Precipitation 50-year average (mm)	39.9	58.0	75.3	58.7	48.7	40.7	312.3
Difference from the average (mm)	-32.3	17.5	-63.1	2.9	3.1	-11.7	-83.6
Temperature 2015 (^{0}C)	11.8	18.3	21.6	24.5	24.9	19.2	20.05
Temperature 50-year average (^{0}C)	11.7	17.5	20.3	22.6	22.1	17.3	18.58
Difference from the average (^{0}C)	0.1	0.8	1.3	1.9	2.8	1.9	8.8

Source: SZTE Tangazdaság Ltd.

Experiment description

The experiment was set in three repeats in random blocks. The size of the parcels was 7.6 m^2 each (10 m x 0.76 m). The fore-crop was corn and after the harvest the tillage involved deep ploughing at 30 cm depth in autumn. After the spring soil works and the seedbed preparation, sowing took place on 13th April. The plant number was 72,000/ha. The corn hybrid in the experiment was DKC

4025 (FAO 340). Foliar fertilization was applied twice (31 May and 6 June) with a dose suggested by manufacturers.

- The fertilisers were put out with back-pack-sprayers. The applied products were the following:
- Algafix (AL) (microbiological bio-stimulator, that contains live algae which produce cytokinin, a plant hormone to help the shoot-growth of the plant),
- Amalgerol (AM) (a product containing plant oils, herb extracts, trace elements and essence), and
- Fitohorm Turbo Zn solution (FZn) (containing Zn, the most important microelement for corn).

The above mentioned products were sprayed out individually and combined with each other as well, so there were six treatments and the control to be examined. The control (untreated) parcels were not sprayed with any of foliar fertilizer products. Apart from foliar fertilisation the parcels received the same agro-technology. The plots were harvested by hand, then the yield of the parcels, grain humidity, shelling rate and thousand-grain weight were measured, out of which the shelled grain yield in May was calculated.

Data processing and statistical methods

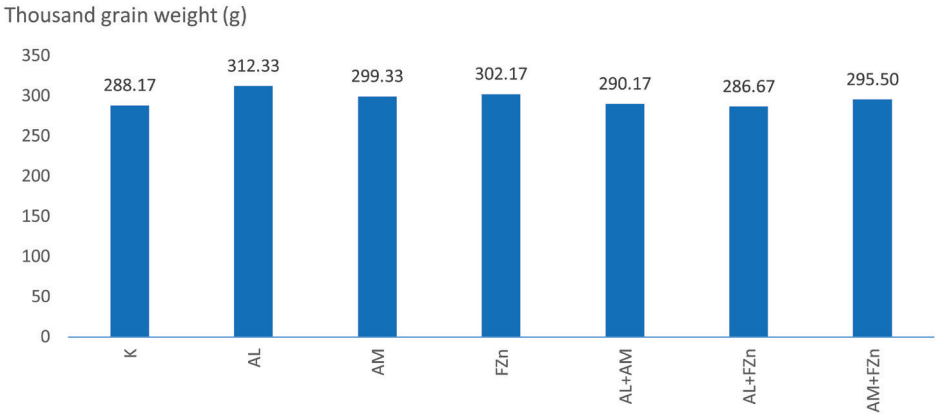
In order to perform the analysis, one-way analysis of variance (ANOVA) and Tukey test were applied. ANOVA was used to clarify whether the means of the different treatments (groups) differ significantly. If ANOVA, based on the F-test, detects significant difference among these means, another test is then applied to determine exactly which means differ significantly from the others. Significant differences between the means of different treatments may highlight the impact of the individual treatments on the analyzed parameter. There are several versions available for comparing means calculated from subsamples of a sample. A relatively simple but effective way is to use the Tukey test (Tukey 1985, Makra *et al.* 2010, 2013).

RESULTS

The effect of foliar fertilisation on the generative factors of corn

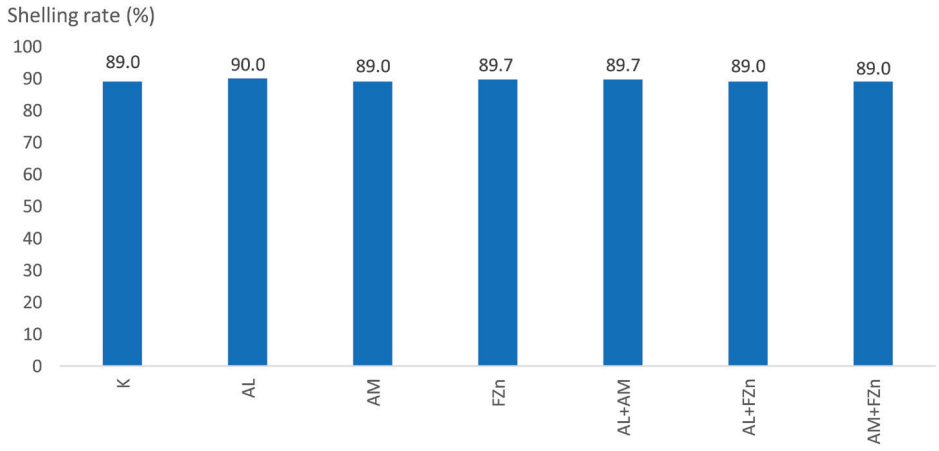
The thousand grain weight is a generative factor, the size of which can be changed best with agro-technical activities. This statement is especially true for the nutrient uptake. Out of the generative factors, thousand grain weight changed most (Figure 1) as a result of foliar fertilisation. Compared to the control (K) the highest increase was reached by spraying with the products not combined

with another one. The thousand grain weight was increased most by the products Algafix (AL) (24.17 g) and Fitohorm Turbo Zn (FZn) (14 g) compared to the untreated parcel. When combining the products, the rate of increase was lower (1.5-7.34 g).



Source: Authors' calculations

Figure 1. The thousand grain weight (g) of corn after different treatments

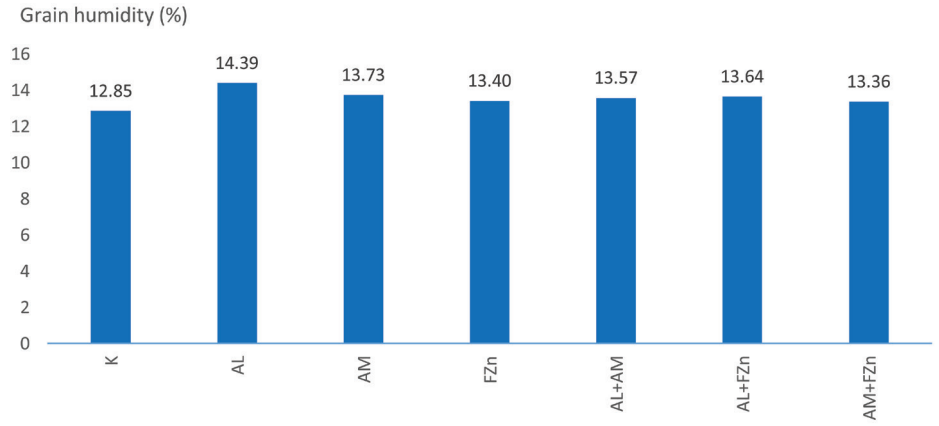


Source: Authors' calculations

Figure 2. The shelling rate (%) of corn after different treatments

The average yield of corn is significantly influenced by the shelling rate of the hybrids. The larger the weight of grain, compared to the weight of the corn-

cob, the higher the yield is. One important objective for breeding is to increase the proportion of the grain. The shelling rates of the new hybrids exceed 80%, sometimes approach 90%. The DKC 4025 type in the research can be described as a hybrid with very good shelling rate, since in the control treatment (K) this value was 89%. The shelling rates of hybrids are greatly influenced by the genetic traits of the hybrids, which can be altered only to a slight extent by various agro-technical treatments. It is also proved by the experiment results, as the value of the control treatment (K) did not change in several cases after the foliar fertilisation. The shelling rate of the tested corn hybrid increased most by Algafix (AL) (1%) as well as Fitohorm Turbo Zn (FZn) and the Algafix+Amalgerol (AL+AM) treatments (0.7%) (Figure 2).



Source: Authors' calculations

Figure 3. The effect of different treatments on the grain humidity (%) of corn

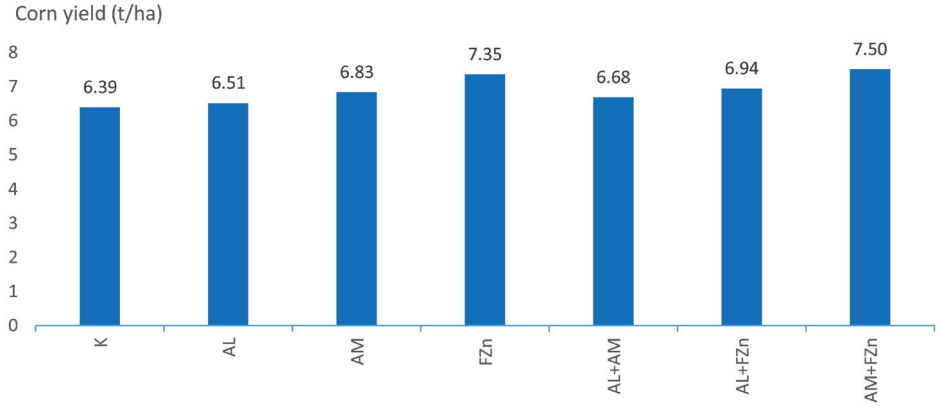
The grain humidity of corn at harvest is one of the most important measures of value. The reason is that among the costs of corn production the cost of drying is a considerable sum. It is important that the hybrids should have low grain humidity at harvest, because in this way the cost of drying can be reduced and at the same time the profitability of corn production can be increased. There are several agro-technical factors influencing the grain humidity of corn at the time of harvest, and one of these factors is the nutrient supply. In the very dry year of 2015 there were low grain humidity values at the time of the harvest. The control parcels (K) dried soon, it was there that the plants became ripe the soonest, and the lowest grain humidity (12.85%) was also measured there (Figure 3). Due to the foliar fertilisation the ripening of the plants was a little later and at the same time higher grain humidity was measured at the time of the harvest (13.40-14.39%). Compared to the control treatments (K), increased grain humid-

ity (0.51-1.54%) was measured in each foliar fertilisation treatment. However, these higher values did not differ significantly from those of the control treatment (K) and drying the corn was not necessary.

The effect of foliar fertilisation on the yield of corn

The yield of the control treatment (K) was low due to unfavourable weather conditions, 6.39 t/ha (Figure 4). Compared to that, higher averages could be measured in all treatments. The rate of yield increase could not be justified statistically in any of them, however.

The certain foliar fertilisers applied individually resulted in 0.12-0.96 t/ha surplus yield compared to the untreated parcel (K). The highest yield increase was achieved by applying Amalgerol (AM) (0.44 t/ha) and Fitohorm Turbo Zn (FZn) solution (0.96 t/ha).



Source: Authors' calculation

Figure 4. The effect of the tested foliar fertilisers on corn yield (t/ha)

When the products were applied in combination, there was 0.29-1.11 t/ha surplus yield compared to the untreated parcel (K). The highest yield increase was measured in the treatments with Algafix + Fitohorm Turbo Zn (AL+FZn) (0.55 t/ha) and Amalgerol+Fitohorm Turbo Zn (AM+FZn) (1.11 t/ha) (Figure 4).

The economic examination of foliar fertilisation

It was examined if the surplus yields of the treatments, compared to the yield of the control treatment, cover the costs of the application of foliar fertilisers (price of product + spraying costs). As far as the product prices are concerned, the price list of an agricultural input distribution company was used. The

spraying cost was 5,000 HUF/ha and two sprayings were calculated. The price of the corn was 44,000 HUF/t.

Table 3. The economic examination of foliar fertilisation

Treatments	Surplus income from surplus yield (HUF/ha)	Price of the products (HUF/ha)	Profit/loss (HUF/ha)
Amalgerol	5,280	42,995	-37,715
Algafix	19,360	18,890	470
Fitohorm Turbo Zn	42,387	17,932	24,455
Algafix+Amalgerol	12,760	51,885	-39,125
Algafix+Fitohorm Turbo Zn	24,200	26,822	-2,622
Amalgerol+Fitohorm Turbo Zn	48,840	50,927	-2,087

Source: Authors calculation

On the basis of Table 3 it can be seen that the profit was positive at only two treatments. In case of the treatment with Algafix there was a minimal profit of 470 HUF/ha, while in case of the Fitohorm Turbo Zn treatment 24,455 HUF/ha profit was achieved, compared to the control. It was due to the amount of the surplus yields: 0.96 t/ha surplus in Fitohorm Turbo Zn treatment and 0.12 t/ha in Algafix treatment. Moreover, in those cases the products were not excessively expensive either. Although a surplus yield of 0.44 t/ha was reached in case of the Amalgerol, the treatment was not profitable because of the high price of the product. When combined treatments were applied, the prices of the products would add up, therefore the additional income from surplus yield did not cover the investment.

CONCLUSIONS

In the study, the effects of three foliar fertilizer products and their combinations on the corn yield and the generative factors were researched. Their application was examined from economic perspective as well.

It was found that owing to the drought in summer, which is unfavourable for corn, relatively low yield was obtained in each treatment (6.39-7.5 t/ha). The Amalgerol + Fitohorm Turbo Zn (7.5 t/ha), the Fitohorm Turbo Zn (7.35 t/ha), and the Algafix + Fitohorm Turbo Zn (6.94 t/ha) treatments had the greatest influence on the quantity of the yield.

Treatments with Zn influenced the size of the yield the most, which indicates that the soil of this area is low in Zn and that might block the achievement of higher yields. The uptake of Zn is also prevented by the very good phosphorus

supply of the soil, because of the antagonism between the two elements. Considering the generative factors, the results of Algafix and Fitohorm Turbo Zn treatments were the best.

The products were also evaluated from the economic point of view. It was examined how much surplus yield can be obtained with the treatments compared to the yield of the control parcel, and whether this surplus can cover the price of the product and spraying. Based on the economic analysis it was found that under the experimental conditions it was the application of Fitohorm Turbo Zn treatment that ensured the highest profit (24,455 HUF/ha). In addition, the application of Algafix treatment was also profitable (470 HUF/ha). In case of Amalgerol the treatment was not recovered because of the high price of the product. Presumably, each treatment and their combinations will be able to result in a higher income in a wet year that is more favourable for the corn.

Considering the results it is obvious that before using any of the products, the nutrient content of the soil must be known and farmers must endeavour to supplement the minimum amounts of nutrients, because this is how they can improve best the efficiency of corn production.

The results of the experiment provide information only in case of the given test area; no general conclusions can be drawn. To make adequate statements, several-years experiment is necessary. The authors wish to know what results they would be able to reach with the treatments in an average as well as in a wet year. Therefore they plan to continue the research.

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