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THE RELATIONSHIP BETWEEN THE CROP, YIELD COMPONENTS, NUTRITION PARAMETERS OF MAIZE AND THE VARIOUS FOLIAR FERTILASERS ANALISED BY ONE-WAY ANOVA

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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, when 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. Both the amount and the quality of crop can be improved with foliar fertilisation. In our experiment we examined the effect of various foliar fertilizer products (Algafix, Amalgerol, Fitohorm Turbo Zn, and their combinations) on the important elements of the yield components of maize, the size and quality of the grain and economic calculations were carried out. The results were evaluated by single-factor analysis of variance (one-way ANOVA). Our aim was to determine for yield components and quality parameters, whether there is significant difference between the means of each treatment-group, i.e. whether the treatment had a significant influence on the mean value of the given parameter. This way, we can get an answer if it is worth dealing with certain treatments for the given yield components and quality parameters.
Keywords: maize, yield components, nutrition parameters, foliar fertiliser, nutrition supply, significance, one-way ANOVA, Tukey-test

INTRODUCTION

In practice, foliar fertilisers can meet only a few percent of the main macro-element demand of plants. Foliar fertilisation cannot replace nutrient uptake through the soil, just supplement it. The foliar fertiliser can get directly to the place of use, the leaf cells and it 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%, [1, 2]. Foliar fertilisation can only be effective if the missing nutrient elements are replaced indeed in the right way and at the right time. Foliar fertilisation tests and experiments must be conducted to check the effect of the fertiliser substances, [3].

Today, our 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. On large areas of plough land there is not enough zinc for the maize and the plant is sensitive to zinc deficiency. In the absence of zinc, the growth of the maize is restrained, the generative organs are damaged, the flower-forming is delayed, or perhaps it will not happen at all. In the past few years the soil examination results showed that due to the intensive production the zinc supply fell back sharply on the good-endowed maize-growing districts of Hungary. 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 supply. A similar phenomenon - the zinc binding – can be observed on alkaline (calcareous) soils. To avoid zinc and other microelement deficiencies, leaf fertilisation is recommended in the 6-8-leave stage of the plant, linking the application with a late post-emergence herbicide treatment. If we apply a foliar fertiliser in a separate run, we should choose the latest possible date for a conventional field sprayer, when we can do the treatment without damaging the plant, when there is enough foliage to the effective uptake of the foliar fertiliser, [4].

The low yield averages in maize production can be due to the fall-back of chemical fertilisation; therefore, the use of fertilisers must be increased in order to reach higher and more consistent amounts of maize, [5, 6, 7, 8, 9, 10, 11].

Nutrients for supplementing basic requirements, mostly the microelements, are taken up by the plant through the leaf. This process is carried out using leaf fertilization or spraying in plant production, [12]. Jakab [13, 14] investigated the effect of foliar fertilisation on the yield of maize. The yield of the control plots ranged from 9.9 to 11.8 t/ha, while that of the treated parcels were between 10.3 and 11.47 t/ha. There was no statistically justifiable difference between the yield of the control and the yields of the foliar- fertilised parcels. Foliar fertilisation resulted in a decrease in crop-changes.

Foliar fertiliser products might be suitable to improve the maize-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, [15, 16, 17, 18].

MATERIALS AND METHODS

Our experiment was carried out in Hungary, in a settlement called Hódmezővásárhely, on the territory of the University of Szeged Pilot Farm Ltd. The experiment was carried out on chernozem soil, which was good in nitrogen, and very good in phosphorus and potassium. The zinc content of the soil, which is the most important micro element for maize, was low (Table 1).

Table 1. Soil test results of the experiment area

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

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 maize. The positive deviation of average temperature together with rainfall deficit had a negative effect on the development of maize, which resulted in low yields.

Various foliar fertilisers were applied during the research. 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 maize 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. The plant number was 72.000/ha.

The hybrid in the experiment was DKC 4025 (FAO 340). This hybrid is typically smaller, its stem is thicker, and its roots are strong. It has excellent yield-stability with good plant-number compensation features and very good stress tolerance. There was a post-emergent weed-control in May. Foliar fertilisation was applied twice (in May and June) with a dose suggested by manufacturers. The fertilisers were put out with backpack-sprayers. The applied products were the following:

- Algafix (AL) (microbiological bio-stimulator, the only product containing live algae from Lake Balaton),
- Amalgerol (AM) (a product containing plant oils, herb extracts, trace elements and essence), and
- Fitohorm Turbo Zn solution (FZn) (containing Zn microelement that improves the rooting and cob-differentiating of maize).
- Treatments combining the above-mentioned products.

Altogether, there were six treatments in the research and the control (untreated) parcel.

In the experiment the single-factor analysis of variance (one-way ANOVA) and Tukey test were used.

The one-way variance analysis (ANOVA) was used to find out whether the mean values of the various treatment groups differed significantly. For example, significant differences between the mean values of the various treatments as groups may reveal the effect of each treatment on the parameter under consideration, [19].

F-test was performed to check whether the difference between the mean values of each group was significant. If this difference is significant, the null hypothesis is rejected based on the test used. At this point, Tukey's test is performed to determine specifically which groups are significantly different, based on the mean values of the given treatment groups, [20].

This test works well with both the accumulation of the type 1 errors and the strength of the test. (If the null hypothesis is stated when using ANOVA, then there is no point in making the Tukey test.) When performing post hoc Tukey test, we first get the differences between the mean values of all possible group-pairs. We compare these differences with a critical value to determine whether they are significant. If the deviation of the averages exceeds this value, the actual difference is significant.

When the Tukey test compares the averages of the treatment groups in pairs it also examines the common impact in addition to the unique effect.

During the test, we first determined the deviation of the averages of all possible group pairs, then compared these differences with the following statistics:

$$HSD = q\sqrt{\frac{MS_W}{n}}, \quad (1)$$

where q is the studentized value set statistics with the appropriate degree of freedom. Its value can be found in a table. The value of MSw is the average square deviation within the group, known from the ANOVA procedure, while *n* is the number of sample elements within the group, [20, 21, 22].

RESULTS AND DISCUSSION

In the framework of the study, experiments were carried out concerning the yield of maize and various parameters of maize, i.e. different treatments and their effect on the subject of the experiment.

The treatments affected the following parameters of maize: grain yield ($t \cdot ha^{-1}$), grain moisture (%), thousand grain weight (g), shelling rate (%), crude protein ($g \cdot kg^{-1}$), crude fat ($g \cdot kg^{-1}$), starch ($g \cdot kg^{-1}$), and crude fibre ($g \cdot kg^{-1}$).

We used one-way ANOVA to find out that the average values of crude protein ($g \cdot kg^{-1}$), crude fat ($g \cdot kg^{-1}$), starch ($g \cdot kg^{-1}$) and crude fibre ($g \cdot kg^{-1}$) content of maize differ significantly in the various treatment groups. Tukey-test was applied to find out exactly in which treatment groups the average values differ significantly.

The crude protein content of maize in the control parcel was 55.87 g/kg. This value was somewhat exceeded by the 56.59 g/kg result of the treatment with Fitohorm Turbo Zn solution as well as that of the Algafix treatment (57.10 g/kg). The foliar fertiliser presenting the best result was Amalgerol, providing a 5 g/kg crude protein plus. The combinations of the various products showed lower values than that of the control, therefore it can be stated that the foliar fertilisers in the research improved the crude protein content of the maize when applied solo, however, when they were combined they decreased it, compared to the control.

Accordingly, treatments No. 3 and 5, as well as No. 3 and 7, showed significantly different results in case of crude protein (g/kg) (Figure 1).

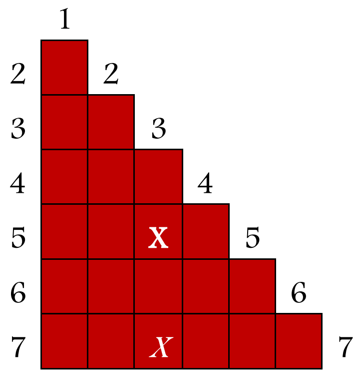

Figure 1. Significant differences in the mean values of crude protein (g/kg) of the treatment groups based on the Tukey-test
(X: significant at p < 0.05% probability level;
X: significant at p < 0.01% probability level)

In the examined foliar fertilisation treatments, the crude fat content of maize mostly decreased; it was only the treatment with Fitohorm Turbo Zn solution (32.97 g/kg) that could exceed the results of the control parcel 29.87 g/kg. The value of this treatment was proved to be statistically higher than that of the control.

The values of the other treatments did not reach that of the control. The lowest values were measured in treatments Amalgerol (23.69 g/kg), and Algafix + Fitohorm Turbo Zn (24.5 g/kg).

In 11 cases out of the 21 possible ones, the mean values of crude fat (g/kg) could be clearly distinguished (Figure 2).

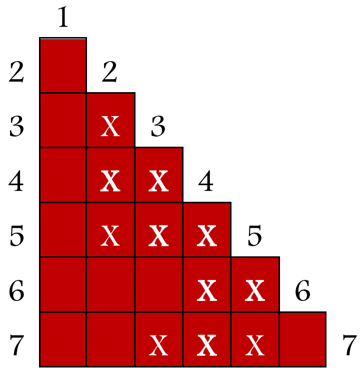

Figure 2. Significant differences in the mean values of crude fat (g/kg) of the treatment groups based on the Tukey-test
(X: significant at p < 0.05% probability level;
X: significant at p < 0.01% probability level)

In the grain of the maize it is the starch that accounts for the highest amount. During our research the highest starch amount was obtained in the Algafix treatment (709.47 g/kg). The second largest value was in the control treatment (702.21 g/kg). In the treatments with the other products we measured lower starch values than that of the control. The starch contents measured in the treatments Fitohorm Turbo Zn, Algafix + Amalgerol, Algafix + Fitohorm Turbo Zn and Amalgerol + Fitohorm Turbo Zn were significantly lower than the values of the control treatment.

In 9 cases out of the 21 possible treatment-pairs, the mean values of starch (g/kg) were visibly outstanding (Figure 3).

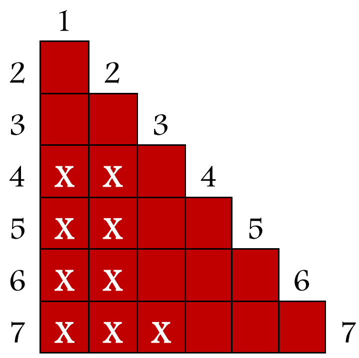

Figure 3. Significant differences in the mean values of starch (g/kg) of the treatment groups based on the Tukey-test
(X: significant at p < 0.05% probability level;
X: significant at p < 0.01% probability level)

Maize presented the highest crude fibre content in the treatment with Algafix (44.75 g/kg). Then the values

of the control (43.95 g/kg), and the Amalgerol treatment (43.28 g/kg) followed. Algafix + Amalgerol and Amalgerol + Fitohorm Turbo Zn treatment pairs showed approximately the same values (40.45 g/kg; 40.48 g/kg, respectively). The two lowest values were obtained with foliar fertiliser treatments with Fitohorm Turbo Zn (39.72 g/kg), and Algafix + Fitohorm Turbo Zn (39.10 g/kg).
In certain cases, we obtained significant differences between the values of the treatments here. The values of Fitohorm Turbo Zn (39.72 g/kg), and Algafix + Fitohorm Turbo Zn (39.10 g/kg) treatments were significantly lower than that of the control (43.95 g/kg), Amalgerol (43.28 g/kg) and Algafix treatments (44.75 g/kg).
In case of crude fibre (g/kg) as well, there are several treatment groups where the mean values are significantly different (Figure 4).

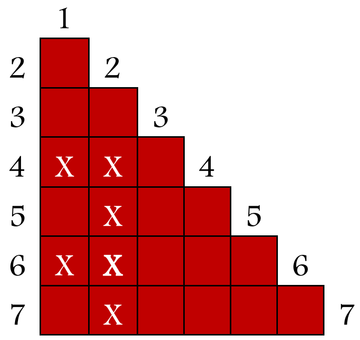

Figure 4. Significant differences in the mean values of crude fibre (g/kg) of the treatment groups based on the Tukey-test
(X: significant at $p < 0.05\%$ probability level;
X: significant at $p < 0.01\%$ probability level)

As for the examined yield component elements, there were no significant differences.
In case of thousand grain weight it was the Algafix product that resulted in the best value (312.33 g), which exceeded that of the control by 24 g. Similarly, good result was achieved by the Fitohorm Turbo Zn solution (302.17 g) as well. Amalgerol (299.33 g) and Amalgerol + Fitohorm Turbo Zn mix (295.50 g) were similar, and Algafix + Amalgerol combination was not much backward either with a result of 290.17 g. The lowest value was produced by the Algafix + Fitohorm Turbo Zn combination (286.67 g), which was even below the value of the control (288.17 g).
Shelling rate is a very important property value of the hybrids indicating the ratio of the grain compared to the whole cob. One important objective of maize breeding to increase shelling rate. Considering the hybrids of today this value is approximately 90%. There were no great differences between the values of the treatment groups in the experiment.
The value of the control parcel was 89% volt, just like the results of the Amalgerolos, Algafix + Fitohorm Turbo Zn mix, and Amalgerol + Fitohorm Turbo Zn treatments. All these were somewhat exceeded by the results Algafix foliar fertiliser, and the Algafix + Amalgerol mix, with a result of 89.7% each. The best shelling rate (90%) was obtained with the application of Algafix foliar fertiliser by itself.
Grain moisture content at harvest is a very important parameter because the lower its value, the lower the cost of drying is. The literature describes cereal grain moisture below 14 % at which drying is not necessary and maize can be stored for longer periods. The droughts of the given year contributed greatly to the rapid drying of maize, which can be seen from the results.
The lowest grain moisture value was measured in the control treatment (12.85%). Similarly, favorable values were obtained when using the Fitohorm Turbo Zn solution (13.40%) and Amalgerol + Fitohorm Turbo Zn mix (13.36%). The other treatment values were slightly higher. The highest values were measured in Algafix treatment (14.39%).
As for grain yield, the values of all treatments were higher than the control value of 6.39 t/ha. The best results were achieved with Amalgerol + Fitohorm Turbo Zn treatment, which showed an increase of 1.11 t/ha compared to the control. This result was approached by the Fitohorm Turbo Zn solution alone (7.35 t/ha), and the Algafix + Fitohorm Turbo Zn treatment did not lag either (6.94 t/ha). In Amalgerol treatment 6.83 t/ha, while in Algafix + Amalgerol treatment 6.68 t/ha was measured.
The lowest result was achieved with Algafix (6.51 t/ha) for grain yield.
Compared with the control, we examined whether the yield surpluses in each treatment cover the costs of applying the fertilisers (product price + application cost). As for the prices, we considered the price list of a company selling agricultural input materials. The cost of the application is 5.000 HUF ha (here we calculated with two applications) and the selling price of the maize was 44.000 HUF/t.
The study found that we received positive income for only two treatments. Algafix achieved a minimum turnover of HUF 470 HUF/ha, while in case of Fitohorm Turbo Zn treatment, a profit of 24.455 HUF/ha was achieved, compared to the control. Due to the high cost of the Amalgerol product, this treatment was not profitable. Regarding the combinations of the products, the total prices of the compositions did not cover the investment.

CONCLUSIONS

In the experiment, the effect of three foliar fertilizer products and their combinations were examined for the yield, yield component elements and some nutritional parameters of maize.
Based on the examinations carried out, it can be concluded that, due to the unfavorable dry weather conditions for maize, relatively low yields were

obtained in each treatment (6.39-7.5 t/ha). Amalgerol + Fitohorm Turbo Zn (7.5 t/ha), Fitohorm Turbo Zn (7.35 t/ha), and Algafix + Fitohorm Turbo Zn (6.94 t/ha) treatments were the most influential on the amount of the yield.

The amount of the crop was the most affected by Zn-containing treatments, indicating that the low Zn-content in the soil of this area could hinder higher yields. The uptake of Zn is also hampered by the very good phosphorus content of the soil due to the antagonism between the two elements. Therefore, we recommend replacing Zn as a leaf fertilizer to reduce the P-Zn antagonism.

In case of yield components, Algafix and Fitohorm Turbo Zn treatments produced the best results. Algafix, Amalgerol, and Fitohorm Turbo Zn treatments had beneficial effects on the examined nutritional parameters of maize. Based on the economic evaluation, it was found that during the experiment, we were able to achieve the highest income (24.455 HUF/ha) using the Fitohorm Turbo Zn treatment. In addition, Algafix treatment was also profitable (470 HUF/ha).

The results show that, for the application of certain products, it is necessary to know the nutrient content of the soil.

Therefore, we must strive to replace nutrients present with lower amount in the soil, which is the best way to increase the efficiency of maize production.

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