ANNALS of Faculty Engineering Hunedoara – International Journal of Engineering
Tome XVIII [2020] | Fascicule 1 [February]

ANNALS of Faculty Engineering Hunedoara – International Journal of Engineering
ISSN 1584 - 2665 (printed version); ISSN 2601 - 2332 (online); ISSN-L 1584 - 2665

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THE RELATIONSHIP BETWEEN THE CROP, NUTRITION PARAMETERS OF WINTER WHEAT AND THE VARIOUS DOSES OF FERTILASER TREATMENTS ANALISED BY ONE-WAY ANOVA

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Abstract: The winter wheat varieties in public cultivation differ in their response to the agrotechnical factors. It is especially true of their fertilizer reaction. Therefore, it is important to determine the natural nutrient-utilising ability and the fertilizer reaction of wheat varieties with different genetics. Being aware of these properties, we can increase fertilizer efficiency, reduce the load on the environment, and optimize sales revenue. Our experiment was carried out in Hungary, in a settlement called Hódmezővásárhely, on the territory of the University of Szeged Pilot Farm Ltd. The soil of the chosen area is meadow soil, with an adequate nitrogen supply, being poor in phosphorus, and good in potassium. During the experiment, besides the control (N0PK0), the following different dosage treatments were applied: Nitrosol, N80PK30, N100PK30, N120PK0, N120PK50, N130PK30 kg/ha. The variety in the experiment was Lucullus. Prior to the harvest, the plant height was measured, and we took plant samples from each parcel and determined some yield components and quality parameters. The results were evaluated by single-factor analysis of variance (one-way ANOVA). Our aim was to determine for yielding elements 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: winter wheat, yield components, nutrition parameters fertilisation, significance, one-way ANOVA, Tukey-test

1. INTRODUCTION

Winter wheat is an extremely demanding plant, requiring great care to reach a large amount of yield safely, the most important factor of which is that the necessary nutrients should be available for the plant. The presence of the major macro-, meso- and micro-elements in the appropriate rate in each phenological phase is also essential in the processes of plant growth and crop production, [1, 2]. Until the 1950s the nutrient supply of the wheat was carried out exclusively through organic manure [3], but today, due to the decline of livestock and the development of technology, roughly 85% is completed with fertilizers, [4]. Several methods of fertilization can be applied, but the effect of fertilization can vary according to cultivation technology and variety, [5].

Based on the experiments of Korobskoi [6] the fertilizer effect is approximately 32.5% in wheat production. In his research into extensive and intensive cultivation technologies, Ladonin [7] found that the effect of fertilization on wheat yields in extensive cultivation technology is 10%, while it is 30% in intensive technology. Professional fertilization can not only increase crop yields and yield safety, but also have a significant effect on yield quality, and thus on baking values, [8].

Experiments and cultivation experiences prove that nitrogen is one of the most important nutrients of wheat because it not only increases the yield, but also improves the baking values of the wheat.

Therefore, an optimal nitrogen supply is of great importance to the quantity and quality of wheat yield, [9]. The main role of nitrogen is the formation of proteins, enzymes and vitamins, the stimulation of vegetative development, and improving wheat quality through spare proteins and gluten, [4].

The uptake of nitrogen is relatively low before the tiller-stage, it is intense and then decreasing in the period of tillering and stalk-forming, however the nitrogen uptake remains, to some extent, up to the end of the vegetation. In plant parts over the earth 65-70% of nitrogen is concentrated in the grain crop at the time of full ripening, [10]. Ducsay and Ryant [11] demonstrated that nitrogen has a positive effect on P, K, Ca, Mg, and S uptake, wet gluten content and crude protein content, irrespective of N fertilization.

In the experiment of Jolánkai [12], nitrogen supply proved to be the decisive factor in yield stability. There was a significant difference between the yields of the control and the treated plots (0.34-2.47 t/ha), which had a great influence on the rate of crop fluctuation. For nitrogen fertilization, note the FVM Decree 59/2008. (IV.29.), which permits a maximum amount of 170 kg of nitrogen substance per hectare. In practice, this value corresponds to 30-35 tons of cattle manure, 28 tons of sheep and pig or 17 tons of poultry manure or approximately 30-100 m3 of slurry, [13].

Growth and protein formation decrease in nitrogen deficiency. The leaves of the plant are yellowish-green with a reddish color of the venation. It can be observed that the stem is thinner and shorter, the root is less branched and is much more elongated. There is less protein in the grain, however more starch and other carbohydrates are formed, [14].

When there is excess nitrogen, the resistance of the plant to disease and winter is reduced, the leaves are wide and dark green, and the tissues are loose, [15]. According to Zsigrai [14], nitrogen over-fertilization or one-sided nitrogen fertilization reduces yields significantly. Darwinkel and Titulaer [16] found that over-dosing N will cause tingling, fungal infections, viral infections, low yields, high protein levels, and poor grain-and-straw rates. The 260-270 kg/ha N doses resulted in a maximum yield, and it was also found that higher N dosages greatly increased protein content.

In the experiments of Sugár [17], N-fertilization had a significant effect on the dry matter accumulation per plant, as well as on the seasonal dynamics of the leaf area and on the size of the flag leaf area.

Phosphorus is found in the plants in inorganic and organic form. Its inorganic form is the orthophosphoric acid, as well as the salts of calcium, magnesium and potassium. It is present as organic in nucleic acids. Nucleic acids are involved in protein synthesis, cell division and growth. Plants take up phosphorus as an orthophosphate ion, [18]. Its intensity is very high during the period of tillering and stalk forming, and the intensity of the uptake decreases continuously during the growing season, while it completely stops during ripening, [19].

Phosphorus contributes to the development of the wheat and to its winter resistance, which has an extremely important role in the period of grain formation, when it is particularly important to supply the plant with phosphorous. However, phosphorus fertilization cannot increase the amount of crop unless the soil is rich in nitrogen and potassium, [5].

In case of phosphorus deficiency, according to Ragasits [20], the wheat is inhibited in vegetative and generative development as well, with poorly tillering, short and thin stems, the leaves are rigid and dark green or bluish-green, with small and low-grained kernels growing on the plants, resulting in less and worse quality crop.

However, considering the phosphorus supply, we must be careful not to cause phosphorus excess in the soil or plant because it may interfere with the other elements such as iron, zinc, calcium, boron, copper manganese, which Lásztity [21] and Németh [22] mentioned.

Potassium is of great importance in plant life processes. The harder soils in our country are usually well supplied with potassium, but the proportion of potassium that can be taken up by the plant is relatively low, [5]. 80-90% of the taken potassium is found in the vegetative plant parts, therefore it is present in large quantities in the by-products of crop production, which is the straw used as a bedding in our present case. When plant residues and roots are processed into the soil, higher amounts of potassium are returned to the cultivation area, however, due to the by-product removal, potassium replacement is needed, [14]. Potassium has an extraordinary role in winter resistance, as it improves the frost tolerance, water management and stress tolerance of plants. The significance of potassium is also the improvement of resistance to diseases, as potassium causes strong cell walls forming in the plant, making it more difficult for the bacteria to access the plant. When the nitrogen potassium ratio is suitable, soluble, small molecules of sugar evolve to larger molecule compounds, thus preventing the growth of pathogens through food shortages, [23]. The highest potassium uptake is observed at the beginning of the growing season until the stem starts, and then gradually decreases.

In the case of potassium deficiency, the plants are excessively bushy, the stems are thin and short, the young leaves are narrow and blue-greenish, the older leaves first become yellow from the tip to the edges, then they have brownish discoloration and finally fall off, [10].

Based on domestic and foreign results it can be stated that the nutrient requirement of wheat is 300-350 kg/ha NPK, which can be modified by biological, ecological and agrotechnical factors. There is a significant difference between the N-reaction and the fertilizer reaction of the different genotypes, [24].

Today, in addition to chemical fertilization, more and more producers apply soil bacterial fertilization. By using these products, the amount of chemical fertilizers can be reduced resulting in the production being more environmentally friendly and economical. Another advantage is that they also have a positive influence on the physical properties of the soil, which is very important for maintaining soil fertility, [25, 26, 27].

The low yield averages in winter wheat 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 crop, [28, 29, 30, 31, 32, 33, 34].

Nutrient supply of wheat can also be done by leaf fertilization. Leaf fertilization, generally, means spraying leaves with diluted solutions or suspensions to correct any nutrient deficiency that can occur, [35]. The advantage of foliar fertilization is that it goes directly to the leaf cells, so that its effect is immediately triggered, without using the soil. In this way nutrient uptake can be sustained in drought as well, [36].

The foliar fertilization of wheat should only be carried out in exceptional cases, so that it can be carried out on sprouts under the snow in early April or early May, when the spring is dry. Foliar fertilization can be an effective method of replacing the microelement deficiencies, [37].

2. 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 soil of the chosen area is meadow soil, with an adequate nitrogen supply, being poor in phosphorus, and good in potassium (Table 1).

Table 1. Soil test results of the experiment area

pH (KCL)	$CaCO_3$ (%)	P_2O_5 (mg/kg)	K_2O (mg/kg)	Humus m/m %	K_A
7.14	8.5	85	561	3.1	55

The amount of precipitation in the growing period of the winter wheat was 533.8 mm, which is 92.8 mm higher than the 50-year average (441.0 mm).

The first crop in the experiment was alfalfa. The basic cultivation for winter wheat was 30 cm deep plowing. This was followed by the widening of basic cultivation, followed by seedbed preparation, and finally by sowing in October. After sowing 50% of the fertilizer doses were put out. Besides the control, 6 different doses of treatment were in the experiment: Nitrosol, N80PK30, N100PK30, N120PK0, N120PK50, N130PK30 kg/ha. All treatments included three repetitions. The size of the plots was 18 m x 50 m. The variety in the experiment was the Lukullus. In addition to fertilization, each parcel has received the same agrotechnology. We harvested plant height prior to harvesting, and we collected plant samples from each parcel and determined some crop-forming elements (e.g. thousand grain weight, kernel length, number of spicules). Each parcel was harvested with a cereal combine harvester.

Plant height measurements were performed by measuring rod. For determining the yielding components (e.g. number of productive shoots, length of kernel, number of spikelets, thousand grain weight), plant samples were taken from the total replication of all treatments before harvesting and delivered to the Laboratory of the Institute of Plant Science and Environment Protection, where we determined the individual yielding elements. The nutrition parameters of winter wheat (e.g. raw protein, moist gluten content, sedimentation value) were analysed using a Mininfra 2000T infrared cereal analyser.

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, [38].

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, [39]. 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:

$$HSD := q\sqrt{\frac{MS_w}{n}} .$$

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, [39, 40, 41].

3. RESULTS AND DISCUSSION

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

The treatments concerned the following parameters of winter wheat: yield (t/ha), length of kernel (cm), number of spikelet (spikelet/kernel), moist gluten content (%), moisture content (%), sedimentation value (ml), crude protein content and plant height (cm).

In addition to the control, the effect of 6 treatments was tested one by one for moist gluten (%), moisture content (%), sedimentation value (ml), crude protein content (%), while to compare the mean values the of yield (t/ha), kernel length (cm) and spikelet-number (spikelet/kernel) and plant height (cm) the test was performed with 7 treatments including the control. In the experiment series, the averages of 3-3-element samples formed the database of the study.

With the one-way variance analysis (ANOVA) it was found that the mean values of the yield (t/ha), the length of the kernel (cm), the number of spikelet (spikelet/kernel), moist gluten (%), moisture content (%), sedimentation value (ml) crude protein content (%) and plant height (cm) differ significantly in the different treatment groups. To determine the differences between the mean values of the treatment group pairs, the Tukey test was used.

The effect of each crop element is displayed in the size of the fruit. It is very important that the genetic capacity of wheat varieties will be utilized as much as possible. For this, it is necessary that the cultivation factors are favourable for winter wheat. In our study, fertilization was the cultivation factor, from the various varieties of which were sought for the most suitable version to use under the experimental conditions.

The yield of the control treatment was 5.70 t/ha. The maximum yield was 8.06 t/ha in the N130PK30 kg/ha fertilizer treatment. The difference in the yield between the two treatments was statistically justified.

According to this, in case of the yield (t/ha) treatments No. 1 and 6, the treatments No. 1 and 7, No. 2 and 7, No 3 and 7 and No. 4 and 7 the average yields were significantly different (Figure 1).

	1	2	3	4	5	6
2						
3						
4						
5						
6	X					
7	X	X	X	X		

Figure 1. Significant differences in the mean values of yields (t/ha) 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)

The kernel-length of winter wheat is a genetically determined property. However, this can be modified by ecological and agrotechnical factors. Of the latter, nutrient supply has the greatest effect on the length of the kernels. Greater kernel-length allows results in greater yield.

In our study, the length of the kernels on 0.5 meters was measured in the fertilizer treatments. In case of treatment without fertilization the kernel-length was 8.87 cm. Due to fertilization, the lengths of the kernels were different (8.32-9.45 cm). The value measured in N120PK0 treatment (9.45 cm) was statistically verifiably higher than the control treatment value (8.87 cm).

When examining the kernel-length (cm) as goal variable, it was only the average values of treatments No. 3 and 5 that differed significantly (Figure 2).

	1	2	3	4	5	6
2						
3						
4						
5			X			
6						
7						

Figure 2. Significant differences in the mean values of kernel-length (cm) 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)

The kernel length also determines the spikelet-number. Therefore, this parameter is determined by the ecological conditions (climatic and soil conditions) and the quality of the applied agrotechnology, in addition to heritability factors. A larger amount of spikelet provides greater yield.

The spikelet-number in the N0PK0 treatment was 20.27 spikelet/kernel. All fertilizer treatments increased the spikelet-number of each kernel. The highest increase (22.03 spikelet/kernel) was observed in N120PK0 treatment, which was statistically higher than the control value.

Out of the treatment groups, we found significant differences between the mean values of the spikelet-number (spikelet/kernel), in group No. 1 and 5 (Figure 3).

	1	2	3	4	5	6
2						
3						
4						
5	X					
6						
7						

Figure 3. Significant differences in the mean values of spikelet-number (spikelet/kernel) 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)

The moist gluten content of winter wheat is a very important quality and qualification parameter. The moist gluten content of wheat flour varies between 25 and 40%. The moist gluten content of the correcting quality winter wheat contains more than 34% of moist gluten, which provides the flour with good water absorption and high gas production capacity. It is important for the manufacturing industry to recognize the gluten characteristics for each type of wheat, because wheat should be mixed according to the desired requirements before grinding.

The moist gluten content of the examined variety also exceeded the minimum value of 34% of the correcting quality category in non-fertilized treatment. In all fertilizer treatments, the moisture content of the type varied significantly compared to the control (N0PK0), but still retained the correcting quality.

In case of the moist gluten content (%), the mean values of treatments No. 1 and 3, 1 and 5, 1 and 6, and 4 and 6 were significantly different (Figure 4).

	1	2	3	4	5
2					
3	X				
4					
5	X				
6	X			X	

Figure 4. Significant differences in the mean values of moist gluten (%) 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)

The grain moisture content at harvest does not appear as an important property value for winter wheat as in corn. The reason is that due to the climatic conditions of our country, the grain moisture content of the wheat drops relatively quickly to the value at which artificial drying is not required even after harvesting.

We wondered how the grain moisture content of winter wheat at the time of harvest is changing in different fertilizer treatments. The highest grain moisture value was observed on the control plot (12.50%). For fertilizer treatments, there were lower values (11.50-12.17%). The moisture values measured in the N120PK0, N120PK50 and N130PK30 treatments proved to be significantly lower than in the other treatments.

Out of the treatment groups of the grain moisture content (%), the averages of groups No. 1 and 4, 1 and 5, 1 and 6, and 2 and 5 and 2 and 6 differed considerably (Figure 5).

	1	2	3	4	5
2					
3					
4	X				
5	X	X			
6	X	X			

Figure 5. Significant differences in the mean values of grain moisture (%) 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)

The sedimentation value of wheat is an index used in international trade that provides information on the quantity, quality and usability of the gluten. The method is also used in breeding experiments and in evaluating agrotechnical experiments. Beside sedimentation value, this quality parameter is also called Zeleny index. Based on the values, three quality categories can be distinguished: from 20 to 30 is weak, from 30 to 40 is medium, while over 40 is good.

The sedimentation value in the control was 73.07 ml. As a result of the different fertilizer treatments, the value of this quality parameter decreased. Compared with the control (N0PK0) treatment (73.07 ml), the values of N100PK30, N120PK50 and N130PK30 treatments were significantly lower (64.87 ml, 64.10 ml, and 63.77 ml, respectively).

When analysing the sedimentation value (ml) as an outcome variable, significant difference was observed between the average values of treatments No. 1 and 3, 1 and 5 as well as treatments 1 and 6 (Figure 6).

	1	2	3	4	5
2					
3	X				
4					
5	X				
6	X				

Figure 6. Significant differences in the mean values of sedimental value (ml) 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)

The crude protein content in winter wheat is a qualitative parameter used in international trade. There are several laboratory methods available (Kjeldahl or Dumas method), however it can be measured with even a faster method, using an infra-red technique. In our study infrared technology was used to determine the crude protein content.

In the N0PK0 treatment, 17.3% crude protein content was measured. In treatments with doses higher than in the N0PK0 treatment, the content of crude protein significantly decreased, ranging from 15.3 to 16.5%. However, this decline did not exceed the corrective quality (12.5%).

As for crude protein content (%), we found significant difference between the mean values of treatments No. 1 and 3, 1 and 5, treatments 1 and 6, 2 and 6, and 4 and 6, (Figure 7).

	1	2	3	4	5
2					
3	X				
4					
5	X				
6	X	X		X	

Figure 7. Significant differences in the mean values of crude protein (%) 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)

Plant height is a very important crop-safety parameter for winter wheat. When the plant height is increasing, the inclination of the wheat to bend also increases. This enhances the appearance of certain fungal diseases, which adversely affect the quantity and quality of the crop. The purpose of the breeders is to have the height of the winter wheat varieties around 1 meter. It is also important how the height of the plant changes with increasing fertilization.

In our study, the control had a plant height of 108.73 cm. Resulted by fertilization, the plants became higher in all cases (from 110.73 to 119.53 cm), and larger vegetative mass was developed. This provides the condition for obtaining higher yields, because more leaves can grow on the plant.

Compared to the control, the height of the plants was significantly higher in all treatments, except for treatments with Nitrosol and N100PK30.

Regarding the treatment groups of plant height (cm), the mean values of treatment groups No. 1, 2 and 3 differed considerably from the averages of groups No 4, 5, 6 and 7. In addition, the mean of group 4 differed significantly from the averages of group 6 and group 7 (Figure 8).

	1	2	3	4	5	6
2						
3						
4	X	X	X			
5	X	X	X			
6	X	X	X	X		
7	X	X	X	X		

Figure 8. Significant differences in the mean values of plant height (cm) 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)

It should be noted that while in the treatment groups of kernel length (cm) (Figure 2) and spikelet number (spikelet/kernel) (Figure 3) the effects of treatments are minimal (significant difference was found among the groups in only one case), we found significantly more marked variations with other outcome variables, which manifested in significant differences in pairwise averages of several treatment groups (Figure 1, Figures 4 to 8).

Therefore, it is worth examining the treatment groups of these latter outcome variables as they respond more sensitively to the treatments than the other outcome variables. It is remarkable that the averages in case of yield (t/ha), in treatment No. 7 (Figure 1), moist gluten content (%) (Figure 4), moisture content (%) (Figure 5) and sedimentation value (ml) (Figure 6) in treatment No. 1 and 6 and plant height (cm) (Figure 8) in treatments No. 4 5, 6, and 7 differed considerably from other treatments. Consequently, it is desirable to analyse the contents of these treatments mentioned above, as they play a decisive role in changing the mean value of the outcome variable.

We also investigated whether the yields produced in various fertilizer treatments cover the costs of the fertilizers we applied. As for fertilizer prices, we calculated with the prices of a fertilizer distributor, and we counted with the expense of double application (one in the autumn and one in the spring). The selling price of the winter wheat was 35.000 HUF/t.

The results indicate it was only the lowest dose N80PK30 treatment that produced a positive income (11,000 HUF/ha). In the higher fertilizer treatments, the surplus revenues did not cover the additional costs and therefore resulted in a loss between 17.000 and 38.000 HUF/ha. These unfavorable profitability conditions, on the one hand, were due to the low selling price of winter wheat and, on the other hand, to the favourable alfalfa fore-crop having beneficial, nutrient-rich effect on the soil.

4. CONCLUSIONS

In the experiment, we examined the effect of various fertilizer treatments on the plant height, the yielding elements of the winter wheat and on the development of some of its quality properties and yields. The results show that in case of winter wheat, a significant amount of precipitation, which fell in the growing season, resulted in a favourable yield (5.70 to 7.34 t/ha).

The yields increased in each treatment compared to the control, due to the favourable fore-crop and favourable climatic conditions.

The length of the kernels was varied (from 8.32 to 9.45 cm), the highest value being measured at N120PK0 treatment.

Different fertilizer treatments had a positive effect on the number of spikelet per kernel. Compared to the control, there was an increase in all treatments, especially in N120PK0 treatment, where the number of spikelet per kernel reached 22.03 value.

Among the quality parameters of winter wheat, moist gluten content was influenced negatively by fertilizer treatments, however, the minimum value of the improvement grade (34%) was exceeded in all cases.

In the grain moisture content at harvest it can be observed that increasing the doses of the fertilizer treatments decreased the moisture content as compared to the control. The lowest moisture content was observed in N130PK30 treatment.

The sedimentation value, which varies between 5 and 90 ml, in all cases decreased compared to the control value after the fertilizer treatments, but still belonged to the high-quality category.

Also, the crude protein content was lower in all fertilizer treatments compared to the control, however it did not pass the correction quality (12.5%) in these cases either.

All fertilizer treatments were beneficial for plant height. Compared to the control, the height of the winter wheat increased with the increasing doses of each treatment.

When considering the economic evaluation, we can conclude that only the smallest dose (N80PK30) fertilizer treatment resulted in a positive income under test conditions, while higher doses produced a loss. The fore crop and the low purchase-price of wheat played a decisive part in that.

In summary, it can be concluded that for the examined winter wheat variety (Lukullus) the N80PK30 treatment was the most optimal for the yield, the quality and the profitability. It can also be stated that the fertilization treatments with different doses had a positive effect on plant height, crop yield and some yield-producing elements.

At the same time, we suggest the University of Szeged Pilot Farm Ltd. applying phosphorus fertilizer in the experimental field of winter wheat to improve the phosphorus supply of the soil so that the lack of phosphorus preferably should not be a crop-restricting factor.

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ANNALS of Faculty Engineering Hunedoara – International Journal of Engineering
ISSN 1584 - 2665 (printed version); ISSN 2601 - 2332 (online); ISSN-L 1584 - 2665

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