Impact of nutrient supply on the relative development of yield components of winter wheat

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Abstract: In the long-term fertilization experiment, at Fülöpszállás, on calcic meadow chernozem soil we carried out experiments in seven growing seasons (2003/2004, 2004/2005, 2005/2006, 2006/2007, 2007/2008, 2008/2009, 2009/2010) with two winter wheat variety (GK Kalász, GK Petur,) in 4 replications, on 20 square meter random layout plots. The yield components were evaluated by kind of Sváb cumulative yield analysis. It can be determined that one-sided N, PK and NPK 2:1:1 rate applications had significant effect not only on yield of winter wheat, but also on yield components determining yield. Compare with the use of different nutrient rates it can be determined that in Fülöpszállás production site of high humus content, good P_2O_5 and K_2O providing ability; in the case of one-sided N application only slightly, but under PK application higher increase in yield component could be realized compared to plants of unfertilized control plots. The NPK 2:1:1 rate application has spectacularly represented the cumulative effect of nutrients, as the appropriate rate of nutrients caused not only the aggregation of the effects of certain nutrient rates, but intensifying influences resulted in redoubling of its results. The higher rates of PK and certain 2:1:1 rate NPK treatments increase the values of yield components only to a lower extent compared to control treatment.

Keywords: winter wheat, nitrogen, phosphorus, potassium, yield components

Received 10 February 2020, Revised 8 April 2020, Accepted 16 April 2020

Introduction

Nutrition supplementation is almost as old as crop production, although for thousands of years farmers have been more instinctively based on traditions, beliefs, habits, and observations rather than following scientifically sound principles. Processing data from several countries, Bocz (1963) clearly found that there was a strong correlation between wheat yield and fertilizer use. Harmati (1987) and Jolánkai (1981) demonstrated the relationship between yield and fertilizer use through domestic examples.

Based on the results of the National Fertilization Continuous Experiments, Debreczeni and Dvoracsek (1994) and Debreczeniné and Ragasits (1996) found that the required quantity of nutrients differs from one production site to another. The optimum nutrient level is influenced not only by conditions of production site but also by the cultivation purpose and economic factors. Thus, the farmers are able to supply nutrients for winter wheat with knowledge of soil analysis, ecological conditions and economic parameters.

According to Harmati (1987) nutrient supply of wheat is mainly (about 85%) by fertilization. In the previous years, winter wheat was rarely fertilized with manure in Hungary (Késmárki and Petróczki 2003), but numerous publications proved the important role of stable manure in the supply of microelements of winter wheat (Kádár and Lásztity 1979, Németh et al. 1987, Kismányoky and Kiss 1998). In contrast, mainly for economic reasons, only nitrogen, phosphorus and potassium are used in fertilization practices (Ragasits 1998).

Lönhardné et al. (1995) concluded that nutrient supply has a great effect on the quantitative parameters of the ears (length of ears, weight of ears, number of grains per ear). In contrast Harmati (1987) the largest part of extra yield caused by fertilizers-which can be appeared in productive tillering (increase number of ear) not in the quantitive parame-

ters of the ears.
According to Lesznyákné (2001), the thousand grain weight is a genetically highly determined yield component that can only be slightly influenced by agrotechnical factors. While Harmati and Gyuris (2002) investigated the effect of P on yield components, it was found that increasing P fertilizers positively changed yield components, thus increasing the number of ears, the number of grains per ears and the thousands grains weight.
According to Jakab, et al. (2017) the fertilization had different effect on the examined generative factors. The thousand seed weight did not change significantly, but the change of length of spike and number of spiklets under the influence of fertilization was significant. Fertilization had a great effect on the length of spike, weight of spike and grain number of spike (Jakab, et al. 2016). Kristó, et al. (2008) have found that the PK and the NPK treatments significantly increased the number of shoots, the number of ears, the number of spikelets.

Materials and Methods

In the long-term fertilization experiment on calcic meadow chernozem soil in Fülöpszállás, evolved by Istvan Harmati in 1982, we made 16 different type of fertilization treatment, which can be use as a different fertilization strategy. We have selected 10 typical treatment from the 16 (Table 1). Fertilization experiments have been carried out in 7 growing seasons (2003/2004, 2004/2005, 2005/2006, 2006/2007, 2007/2008, 2008/2009, 2009/2010) with 2 winter wheat variety (GK Kalász, GK Petur) with 500 seed/m^2 density, in 4 replications, on 20 m^2 random layout plots.
The yield components were evaluated with Sváb-type cumulative yield production analysis (Sváb 1961, 1962). In our yield component investigations plants and shoots (deriving from unit area of 0.25 running meter) have been removed from the internal rows of the plots. The samples have been marked with the help of a measuring rod. The cumulative yield production analysis gives opportunity for graphic representation of plant development, where horizontal axle (x) represents yield components (end products of different development stages) per unit area in developmental order, and vertical axle (y) indicates the percent value of yield components referring to a basis for comparison. In the course of cumulative yield production analysis the followings are considered as yield components: A=number of seeds per unit area, B=number of shoots per unit area, C=number of ears per unit area, D=number of spikelets per unit area, E=number of grains per unit area, F=grain weight per unit area.

Results

As a result of the investigation in Fülöpszállás, data from yield components were made by variance analysis of are in Table 2. All of the treatments have a significant effect on the number of shoots, grains, and grain weight of winter wheat per unit area in 0.1%. It was significant 1% on the number of spikelets, 5% on the number of ears.
All of the investigated yield components and the fertilizer (A) were 0,1% level of significance. While the winter wheat species (B) was 5% level of significance in the case of the number of ears per sample. From the other parameters we couldn't get statistically reliable results. Growning seasons (C) has a significant effect on the number of shoots, spikelets, and grain weight per unit area in 5%, but there was no influence on the number of ears and grains.
From the interactions fertilizer × winter wheat species (A × B) no significant difference could be proved concerning to the yield components. While the fertilizer ×

DOI: 10.18380/SZIE.COLUM.2020.7.2.25

Table 1. Data of nutrient applications in the experiment.

№ of the application	Name of application	N	P_2O_5	K_2O
		kg ha^{-1} active agent		
1	control	0	0	0
2	*N1*	30	0	0
3	*N2*	60	0	0
4	*N2*	90	0	0
5	*PK1*	0	30	30
6	*PK2*	0	60	60
7	*PK3*	0	90	90
8	*NPK1*	60	30	30
9	*NPK2*	120	60	60
10	*NPK3*	180	90	90

Table 2. Results of variance analysis of yield components (MS).

	df	number of shoots	number of ears	number of spikelets	number of grains	grain weight
Repeat	3					
Total treatment	559	211266.30***	145157.60*	29245401.29**	106041703.5***	188175.05***
Fertilizer (A)	9	443.64***	363.25***	220919.21***	1179419.18***	2934.15***
Variety (B)	1	232.72*ns*	92058*	127912.2*ns*	46537.55*ns*	16.35*ns*
Growing season(C)	6	852.84*	418.38*ns*	167867.90*	198952.26*ns*	821.59*
Intercepts:						
A × B	9	9.80*ns*	9,85*ns*	2569.28*ns*	4221.37*ns*	11.39*ns*
A × C	54	20.95*	1245*ns*	4355.68*	1282.85*	30.49*
B × C	6	124.35***	115.18***	30328.22***	5622.59***	167.00***
A × B × C	54	12.38***	8.67***	2397.28***	767798***	16.87*ns*
Error	420	3.07	2.24	813.84	2118.67	15.98

*The mean difference is significant at the P=5% level.
**The mean difference is significant at the P=1% level.
***The mean difference is significant at the P=0.1% level.
ns: The mean difference is non- significant.

grownning seasons (A × C) interaction have a significant effect on the number of shoots, spikelets, grains and grain weight per unit area in 5%. Number of ears we couldn't get statistically reliable results. In the winter wheat species × growing seasons (C) interaction have significant effect on all of the yield components in 0.1% Fertilizer × winter wheat species × grownning seasons (A × B × C) interactions have a significant effect on the number of shoots, ears, spikelets, and grains per unit area in 0.1%. Grain weight we couldn't get statistically reliable results.

We can see the effect of different level fertilizer treatments of the relative process of development of winter wheat in

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Figure 1, where the level 100% is the yield components of the control, unfertilized treatment for a long time ago. On the development graph yield components were signed capital letters of the ABC. A= number of seeds/sample, B=number of shoots/sample, C=number of ears/sample, D=number of spikelets/sample, E=number of grains/sample, F=grain weight/sample. In the investigation of the effect of different nutrient rates, the $N_{30}P_0K_0$ (N1) application had almost no effect to the winter wheat tillering tendency, furthermore $N_{60}P_0K_0$ (N2) and $N_{90}P_0K_0$ (N3) applications increased 6% and 5% of the number of shoots per unit area. Based on the graph of the different level of N applications influenced the number of spikelets per unit area positively, compared with the control unfertilized treatment in the case of the 30 kg ha^{-1} N application (N1) increased the number of spkelets per unit area in 4%, 60 kg ha^{-1} N application (N2) increased in 3%, and 90 kg ha^{-1} N application (N3) increased in 10%. By linking C and D end products of different development stages with line facing up, which means the different level of N applications had obviously positive effect on the number of spikelets. The effect of one-sided, different level nitrogen applications increased the number of grain yield by 11%, or 23%, compared with the control unfertilized plots. By linking E and F end products of different development stages with line facing down, in the case of 30 kg ha^{-1} (N1) and 90 kg ha^{-1} (N3) applications, which means these treatments had an effect on thousand-seed weight.

The different levels of phosphorous and potassium applications without nitrogen (PK1, PK2, PK3) show very similar development graph. Compared with the control, unfertilized plots these applications increased the number of shoots per unit area in 11-22%, the number of ears per unit area in 11-23%, the number of spikelets per unit area in 23-33%, and the number of grains per unit area in 15-27%. The end products of different development stages, that is grain weight per unit area increased compared with the control, unfertilized plots, in case of the $N_0P_{30}K_{30}$ (PK1) application in 28%, $N_0P_{60}K_{60}$ (PK2) application in 47%, $N_0P_{90}K_{90}$ (PK3) application in 43%. It means the greatest PK application (PK3) without nitrogen increased much less extent in yield than $N_0P_{60}K_{60}$ (PK2) application. The PK treatments influenced tillering tendency, spikelets development, and thousand-seed weight favorably, in contrast had negative effect on the number of grains.

By investigating the winter wheat average growing seasons, and species NPK 2:1:1 rate applications (NPK1, NPK2, NPK3), compared with the control, unfertilized plots, their tendency of the development lines were similar. In case of $N_{60}P_{30}K_{30}$ application (NPK1) the number of shoots/sample were 30%, the number of ears were 33%, number of spikelets were 55%, number of grains were 72%, and the grain weight were 105% more than the control, unfertilized plots. At the application $N_{120}P_{60}K_{60}$ (NPK2) the number of shoots/sample were 39%, the number of ears were 37%, number of spikelets were 73%, number of grains were 102%, and the grain weight were 155% more than the control, unfertilized plots. At the application $N_{180}P_{90}K_{90}$ (NPK3) the number of shoots/sample were 51%, the number of ears were 56%, number of spikelets were 99%, number of grains were 147%, and the grain weight were 184% more than the control, unfertilized plots.

On the Figure 2 we represented the development graph of the two determined variety: yield components of GK Kalász variety gives level 100%, compared with GK Petur's development line. By investigated the average years and nutrient treatments of GK Petur it seems had less tillering tendency than GK Kalász. Moreover, shoots in

DOI: 10.18380/SZIE.COLUM.2020.7.2.25

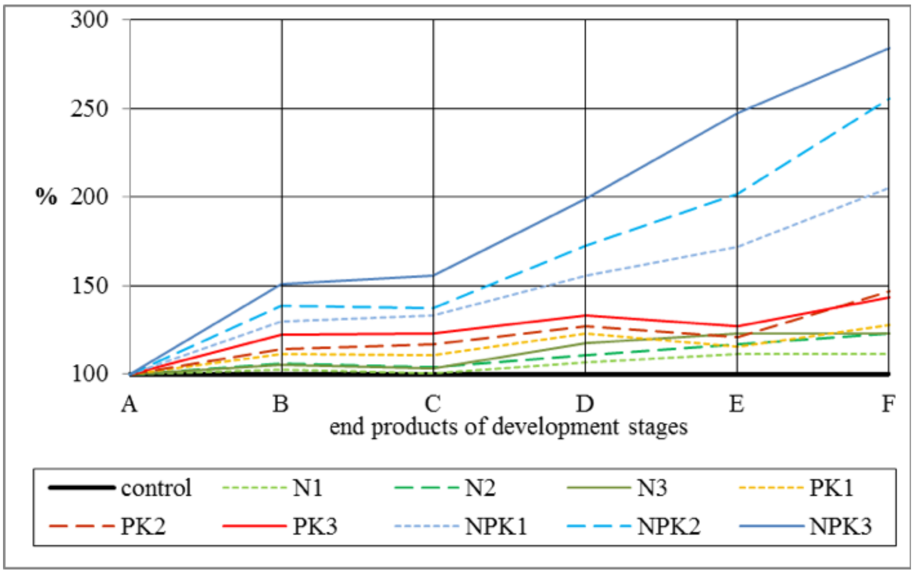

Figure 1. Relative development of winter wheat on different fertilizer treatments in average of 7 year and 2 varieties.

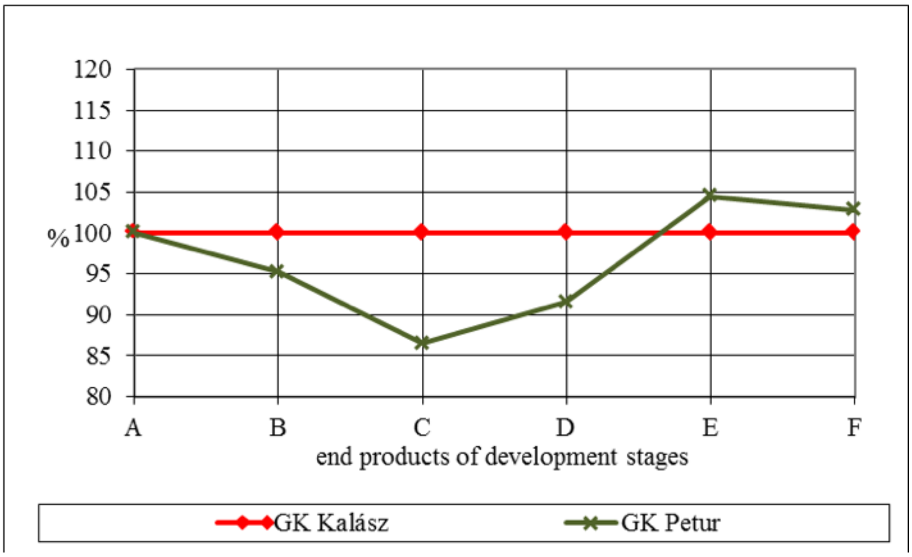

Figure 2. Relative development of winter wheat on experimented two varieties.

GK Petur were unproductive, which means there is no spikelets. We can see it by B and C end products of different development stages line tendency. Development line tendency of C-D and D-E show that GK Petur has more spikelets and number of grains, than GK Kalász. It means the number of grains per unit area is also much more than GK Kalász. Although in the investigation of the average years and nutrient treatments of the thousand-seed weight of GK Kalász was much bigger (0.7g), than GK Petur, grain yield per unit area is less in 3%.

On the Figure 3 we can see the relative development of winter wheat on different growing seasons. The 100% level means the determined yield components during the 7 growing season. In the year of 2005/2006,

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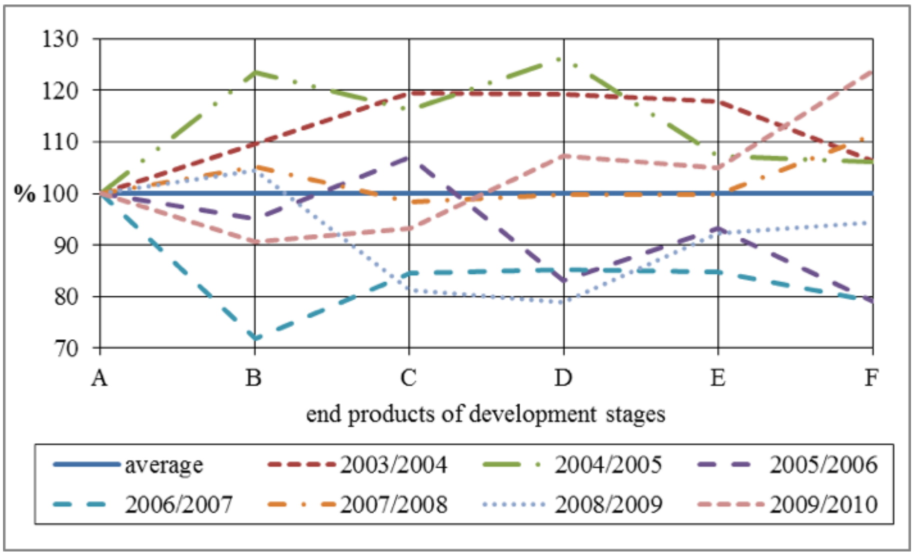

Figure 3. Relative development of winter wheat on different growing seasons.

2006/20007 and 2009/2010 tillering tendency of winter wheat was below the average because of the low amount of precipitation in the autumn and winter. In contrast in the year of 2004/2005 it was rainy moderately warm in autumn, which was quite favourable for initial development and tillering tendency of winter wheat. Because of the rainy, mild weather of March and April was positive for the number of ears and spikelets in the years of 2003/2004, 2004/2005 and 2009/2010. In 2007/2008 and 2009/2010 the weather in May and June were favourable for graining, this was the reason why thousand-seed weight of winter wheat was much above than the determined average years.

Discussion

Nutrient supply for winter wheat is very important in the current level of management, usually most part of it means the use of fertilizer. Nowadays there are a lot of new winter wheat variety in commercial growing, it plays much significant role to recognize nutrients supply treatments to get economical, sustainable and environmentally friendly wheat cultivation. In our nutrient rate investigations the effect of different nutrient application strategies on the most important yield components influencing yield of winter wheat varieties have been studied.

It can be determined that one-sided, different level nitrogen applications increased yield components (number of shoots, ears, spikelets, grains, and grain weight per unit area) in slightly rate. On the basis of our results it can be determined the same like Lásztity (1987) that N applications had a great effect on grain weight, number of grains, in contrast one-sided N applications decreased thousand-seed weight of winter wheat.

All of the determined species and growing seasons the different levels of phosphorous and potassium had positive effect on the yield components of winter wheat all the time, compared with the end products of different development stages of the control, unfertilized plot. In our experiments is the same with Liakas et al. (2001), as PK rations increased as the number of shoots increased. Only P and K application plots had higher tillering tendency, increased number of spikelets and seed size, according to Rag-

DOI: 10.18380/SZIE.COLUM.2020.7.2.25

asits (1983) too. In contrast PK application without nitrogen was negative for the fertilization of flowers, because the number of grains per one spikelets was lower than the control, unfertilized plots. NPK application in 2:1:1 rate show nutrients cumulative effect spectacularly. The end products of different development stages, yield per unit area also increased, just like the number of shoots, ears, spikelets, and grains. From the derived yield components the number of spikelets per ears, number of grains per spikelets and thousand-seed weight were also increased.

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DOI: 10.18380/SZIE.COLUM.2020.7.2.25