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EFFECTS OF CROP YEAR AND NUTRIENT SUPPLY ON THE YIELD OF DIFFERENT WINTER WHEAT VARIETIES ON CHERNOZEM SOIL

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Abstract. *The nutrient uptake and fertilizer response of wheat varieties of different genotypes with different dosage of fertilizers was examined in different crop years. In the analyzed crop years we were searching for answers to how different climate and crop year conditions effect the yield. The yield of five winter wheat genotypes was investigated in three different growing seasons on chernozem soil. The results suggest that the genotype and the nutrient supply had a considerable influence on the yield, while the growing season modified the yield in a significant manner.*

Keywords: winter wheat, fertilizer response, effect of season, yield

1. Introduction

According to Harnos and Erdélyi [1], the yields are greatly determined by the temperature and the precipitation. The average temperature of the April-June period and the amount of precipitation from March until June have a great effect on the yield of winter wheat. L-Baeckstrom et al. [2] claim that the yield of wheat is determined by the year (precipitation and temperature), the agrotechnique and the nitrogen doses. Gutierrez et al. [3] found differences in yield due to genotype's differences. Different wheat varieties responded to specific environmental factors with different yields [4, 5]. Somnez [6] concluded that the yield and grain protein content were determined by the year, the genotype and the nutrient supply. According to Balla and Veisz [7], in response to higher temperature, wheat turns yellow due to a decrease in the chlorophyll content, which causes a drastic decline in photosynthetic activity. The resulting acceleration of the grain-filling process leads to yield loss in the case of varieties whit poor heat stress tolerance.

2. Materials and methods

The long-term experiment was carried out at the Látókép Experimental Station of the Institute of Crop Sciences, University of Debrecen. The experimental station is located 15 km west of Debrecen in the Hajdúság. The soil of the experiment is calcareous chernozem and can be classified into the loam category, its pH is near neutral and it has medium humus content.

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The long-term experiment was set up in 1983. Our study contains the results of the period 2010-2012. The small-plot field experiment was set up in a split-split-spot design in four replications. Six fertilization levels were applied in the treatments. In addition to the control, the basic dosage of N=30 kg ha^{-1}, P_2O_5=22.5 kg ha^{-1} and K_2O=26.5 kg ha^{-1} and 2-,3-, 4- and 5-fold dosages were applied. The total P and K dosages were applied in the autumn, 50% and 50 % of the N fertilizer dosages were applied in the autumn and in the spring. The forecrop was sweet maize.

In the experiment five different genotypes of winter wheat were examined: GK Öthalom, Lupus, Pannonikus, Mv Toldi, Genius.

Due to the dry weather of the first half of October in crop years 2009/2010, wheat sprouted very slowly, its shooting remained heterogeneous (Table 1). From mid-October precipitation was above average, and temperatures were favorable for development and firming of the wheat stands.

Table 1) Main meteorological data of the tested crop years (Debrecen, 2010-2012)

	Oct.	**Nov.**	**Dec.**	**Jan.**	**Feb.**	**Marc.**	**Apr.**	**May**	**Jun.**	**Total/ Average**
Precipitation (mm) 2009/2010	79.3	78.3	54.9	48.8	58.6	14.4	83.9	111.4	100.9	630.5
30 year's average	30.8	45.2	43.5	37.0	30.2	33.5	42.4	58.8	79.5	400.9
Difference	*+48.5*	*+33.1*	*+11.4*	*+11.8*	*+28.4*	*-19.1*	*+41.5*	*+52.6*	*+21.4*	*+229.6*
Precipitation (mm) 2010/2011	22.8	52.9	104.2	19.2	16.8	35.1	15.6	52.3	22.0	340.9
30 year's average	30.8	45.2	43.5	37.0	30.2	33.5	42.4	58.8	79.5	400.9
Difference	*-8.0*	*+7.7*	*+60.7*	*-17.8*	*-13.4*	*+1.6*	*-26.8*	*-6.5*	*-57.5*	*-60.0*
Precipitation (mm) 2011/2012	18.1	0.0	71.1	28.0	17.8	1.4	20.7	71.9	91.7	*320.7*
30 year's average	30.8	45.2	43.5	37.0	30.2	33.5	42.4	58.8	79.5	400.9
Difference	*-12.7*	*-45.2*	*+27.6*	*-9.0*	*-12.4*	*-32.1*	*-21.7*	*+13.1*	*+12.2*	*-80.2*
Temperature (°C) 2009/2010	11.4	7.6	2.3	-1.1	0.5	7.6	11.6	16.6	19.7	8.47
30 year's average	10.3	4.5	-0.2	-2.6	0.2	5.0	10.7	15.8	18.8	6.94
Difference	*+1.1*	*+3.1*	*+2.5*	*+1.5*	*+0.3*	*+2.6*	*+0.9*	*+0.8*	*+0.9*	*+1.5*
Temperature (°C) 2010/2011	6.9	7.7	-1.7	-1.2	-2.5	5.0	12.2	16.4	20.5	7.03
30 year's average	10.3	4.5	-0.2	-2.6	0.2	5.0	10.7	15.8	18.8	6.94
Difference	*-3.4*	*+3.2*	*-1.5*	*+1.4*	*-2.7*	*0.0*	*+1.5*	*+0.6*	*+1.7*	*+0.1*
Temperature (°C) 2011/2012	8.6	0.6	1.5	-0.6	-5.7	6.3	11.7	16.4	20.9	6.6
30 year's average	10.3	4.5	-0.2	-2.6	0.2	5.0	10.7	15.8	18.8	6.9
Difference	*-1.7*	*-3.9*	*+1.7*	*+2.0*	*-5.9*	*+1.3*	*+1.0*	*+0.6*	*+2.1*	*-0.3*

This favorable weather continued also in November and December. In January and February, the amount of precipitation exceeded and average temperature was milder than the average of many years. Precipitation was less only in March. During the months in the spring and the summer, the considerable amount of precipitation had a negative effect for the generative processes of winter wheat, and it caused significant extent of lodging and yield loss. 229.6 mm more rain fell than the average of many years (400.9 mm), and the average temperature of the growing season was 1.5 °C higher than the average of many years (6.9 °C).

In crop year 2010/2011, due to the colder weather in October, shooting of winter wheat stands was drawling, but the warmer weather in November had a positive impact on the development of the stand. The snow provided enough protection against winter frosts for wheat stands. The favorable warm spring weather had positive impact on the stands, and accelerated their growth. The low rainfall in June had an adverse effect on grain filling processes. In early July, rainy and cool weather helped the translocation processes, but had delayed the harvest. 60 mm less rain fell than the average of many years (400.9 mm), and the temperature of the growing season was 0.1 °C higher than the average of many years (6.9 ° C).

Crop year 2011/2012 was extreme for winter wheat production. Due to dry months of October and November in 2011, shooting and initial development became drawling. In the wetter winter months, winter wheat varieties were able to gain strength, but the subsequent dry and warmer than average spring had a negative impact on vegetative development of wheat. In early summer, May and June, the rainfall and favorable temperatures positively affected the grain filling processes. 80.2 mm less rain fell than the average of many years (400.9 mm), and average temperature of the growing season was 0.3 °C lower than the average of many years (6.9 ° C).

The experimental data were evaluated by programmes Microsoft Excel 2013, and SPSS 24.0 for Windows. Results were analyzed by two-way analysis of variance based on the method of Sváb (1981). Impact of genotype, nutrient management and crop year on yield was determined by partitioning variance components.

3. Results

In crop years 2009/2010 the lowest yield was gained from varieties GK Öthalom (2896 kg ha^{-1}) and Lupus (3110 kg ha^{-1}), while with varieties Pannonikus (3850 kg ha^{-1}) and Mv Toldi (3812 kg ha^{-1}) good yield was measured (Table 2). In the control treatment, variety Genius (4275 kg ha^{-1}) had the maximum yield. Maximum yields were realized at lower nutrient levels. The optimal nutrient level in case of varieties GK Öthalom (5175 kg ha^{-1}), Lupus (5675 kg ha^{-1}) and Mv Toldi (5196 kg ha^{-1}) was N_{60}+PK. In case of Pannonikus (5271 kg ha^{-1}) and Genius (5986 kg ha^{-1}) dose of N_{30}+PK was the best in crop year 2010. In crop year 2010/2011 in the control plots variety Genius (4019 kg ha^{-1}) had also good results as well as variety Pannonikus. Lupus (3102 kg ha^{-1}), GK Öthalom (3019 kg ha^{-1}) and Mv Toldi (3316 kg ha^{-1}) had low average yield. The lowest maximum yield (6150 kg ha^{-1}) was obtained with variety Lupus at N_{90}+PK nutrient level. Variety GK Öthalom also had low yield maximum (6819 kg ha^{-1}), variety Mv Toldi reached good yield maximum (7620 kg ha^{-1}). The highest maximum yields were reached with Pannonikus (8224 kg ha^{-1}) at N_{120}+PK nutrient level, and with variety Genius (8462 kg ha^{-1}) at optimal nutrient level (N_{150}+PK).

Table 2) Effect of year and fertilization on the yields (kg ha^{-1}) in the long-term experiment (Debrecen, 2010-2012)

Crop year	Variety	GK Öthalom	Lupus	Pannonikus	Mv Toldi	Genius	*Average*
	Treatment	**Yield kg ha^{-1}**					
2010	***Control***	2986	3110	3850	3812	4275	**3607**
	N_{30}+PK	4750	5250	**5271**	4576	**5986**	**5167**
	N_{60}+PK	**5175**	**5675**	4779	**5196**	5550	**5275**
	N_{90}+PK	4680	5350	4103	5013	4972	**4824**
	N_{120}+PK	4375	5476	3725	4850	4796	**4644**
	N_{150}+PK	3429	5063	3561	4927	4600	**4316**
	Average	**4233**	**4987**	**4215**	**4729**	**5030**	-
	$LSD_{5\%\ Genotype}$ 177		**$LSD_{5\%\ Fertilization}$ 179**		**$LSD_{5\%\ Interaction}$ 401**		
2011	***Control***	3019	3102	4719	3316	4019	**3635**
	N_{30}+PK	4682	3814	5927	4542	5436	**4880**
	N_{60}+PK	5745	4873	7072	6119	6717	**6105**
	N_{90}+PK	6172	**6150**	8123	6526	7105	**6815**
	N_{120}+PK	6500	5902	**8224**	6938	7736	**7060**
	N_{150}+PK	**6819**	5718	7692	**7620**	**8462**	**7262**
	Average	**5490**	**4927**	**6960**	**5844**	**6579**	-
	$LSD_{5\%\ Genotype}$ 250		***$LSD_{5\%\ Fertilization}$* 230**		***$LSD_{5\%\ Interaction}$* 514**		
2012	***Control***	3176	3132	4210	3607	3610	**3547**
	N_{30}+PK	4513	4610	5303	5676	5751	**5171**
	N_{60}+PK	5360	5427	6650	6163	6642	**6048**
	N_{90}+PK	5548	5688	6925	6307	6804	**6254**
	N_{120}+PK	5810	6129	**7880**	6509	**7127**	**6691**
	N_{150}+PK	**6175**	**6408**	8139	**6868**	7209	**6960**
	Average	**5097**	**5232**	**6518**	**5855**	**6191**	-
	$LSD_{5\%\ Genotype}$ 246		**$LSD_{5\%\ Fertilization}$ 250**		**$LSD_{5\%\ Interaction}$ 558**		

In crop year 2011/2012, varieties Lupus (3132 kg ha^{-1}) and GK Öthalom (3176 kg ha^{-1}) had the lowest control yield. Mv Toldi (3607 kg ha^{-1}) and Genius (3610 kg ha^{-1}) had nearly the same average yield. The highest yield in the control plots was achieved by variety Pannonikus (4210 kg ha^{-1}). The lowest yield maximum was gained with GK Öthalom (6175 kg ha^{-1}). Lupus (6408 kg ha^{-1}) and Mv Toldi

(6868 kg ha^{-1}) reached a medium yield maximum. The best yields also in this crop year were achieved by Pannonikus (7880 kg ha^{-1}) and the Genius (7127 kg ha^{-1}) at N_{120}+PK nutrient level.

Evaluating the three crop years together (Table 3), in average of the varieties it can be concluded that natural nutrient assimilation capacity of the varieties was the best in 2011 (3635 kg ha^{-1}), while the relatively lowest average yield (3547 kg ha^{-1}) was gained in the control treatment in 2012.

Table 3) Effects of fertilization on the yield and the fertilizer utilization capacity in the average of varieties (Debrecen, 2010-2012)

Crop year	Control kg ha^{-1}	Maximum yield kg ha^{-1}	Yield increment kg ha^{-1}	NPK dose of maximum yield	Specific surplus of max. yield kg
2010	3607	5461	1854	***N_{30-60}+PK***	15.70
2011	3635	7455	3820	***N_{90-150}+PK***	11.14
2012	3547	6960	3413	***$N_{120-150}$+PK***	13.42
Average	**3596**	**6625**	**3029**	**--**	**13.42**

The varieties reached the lowest maximum yield (5461 kg ha^{-1}) in rainy year 2010, while the best yield (7455 kg ha^{-1}) could be measured again in the average crop year 2011. Yield increment of the varieties was the lowest in 2010 (1854 kg ha^{-1}), it was moderate in 2012 (3413 kg ha^{-1}), while in 2011 it was the highest (3820 kg ha^{-1}). The optimal levels of nutrient supply was low (N_{30-60}+PK) in 2010, then due to the extreme wet weather, in 2011, they varied between N_{90-150}+PK levels, while in 2012, this level was $N_{120-150}$+PK, probably due to the lower fertilizer utilization caused by draught and disturbances in nutrient uptake caused by water shortages.

The yield increment per applied 1 kg of NPK active ingredient was the highest (15.70 kg) in 2010, it was medium (11.14 kg) in 2011, and it was the lowest (8.64 kg) in 2012.

Analyzing the nutritional response of varieties in three-year average (Figure 1) it can be concluded that varieties can be classified into two groups. GK Öthalom, Lupus and Mv Toldi had a poor response to extreme and different crop years, they performed a poor natural nutrient utilization and weak capability of fertilizer utilization. In contrast, varieties Genius and Pannonikus had a good natural nutrient utilization character and had good response to fertilizers in each of the three years, in spite of varying crop year effects.

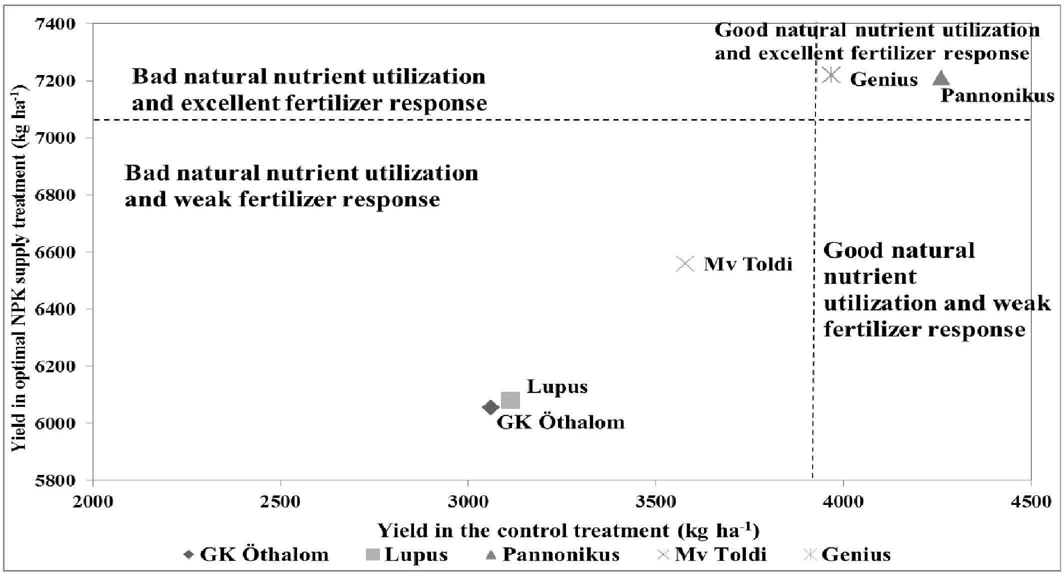

Fig. 1. Types of nutrient response of the examined winter wheat genotypes in the average of the three crop years (Debrecen, 2010-2012)

By dividing of variance components, we were able to accurately quantify the effect of the crop year, the genotype and the nutrient supply to the harvested yield. To determine the significance of the studied factors, we took the minimum values measured on control nutrient levels as a base, and we divided the increase belonged to maximum values reached with the combination of the analyzed parameters among the analyzed factors.

In 2010, in the control treatment, the average yield was 3607 kg ha^{-1} the average of maximum yields was 5461 kg ha^{-1}, which was 1856 kg ha^{-1} yield increment (Figure 2). 71% of the yield increment was due to genotype, which was 1316 kg ha^{-1} increase in yield. The nutrient supply contributed to the increase in only 29% (538 kg ha^{-1}). The minor role of nutrition can be explained by the low yield maximums due to extreme amount of precipitation in crop year 2010, and varieties reach the highest yield at N_{30-60}+PK nutrient levels. The more considerable role of genotype expressed in percentage proved that to achieve higher maximum yields the varieties had to have good ability to adapt (better endurance against lodging and diseases) to extreme environmental conditions. In average crop year 2011, average of the control treatments was 3635 kg ha^{-1}, while average of maximum yields was 7455 kg ha^{-1}, which gave 3820 kg ha^{-1} yield increment. In this year, the genotype caused 25% (972 kg ha^{-1}), but the nutrient supply contributed to 75% (2848 kg ha^{-1}) of production of yield increment. The result can be explained by the fact that the in average crop year not that ability of varieties to adapt but their better nutrient response played a greater role in yield increment production. In 2012, average of the harvested yield was 3547 kg ha^{-1} in the control plots, while the average of maximum yields was 6960 kg ha^{-1}, i.e. 3413 kg ha^{-1} yield increment was gained. The genotype resulted 26% (904 kg ha^{-1}), while nutrient treatment caused 74%, which equals 2509 kg ha^{-1}, of formation of the yield increment. Also in 2012, the nutrient response affected more significantly the production of yield increment, due to the fact that nutrients distributed in the drier spring period of 2012, was solubilized to a lesser extent.

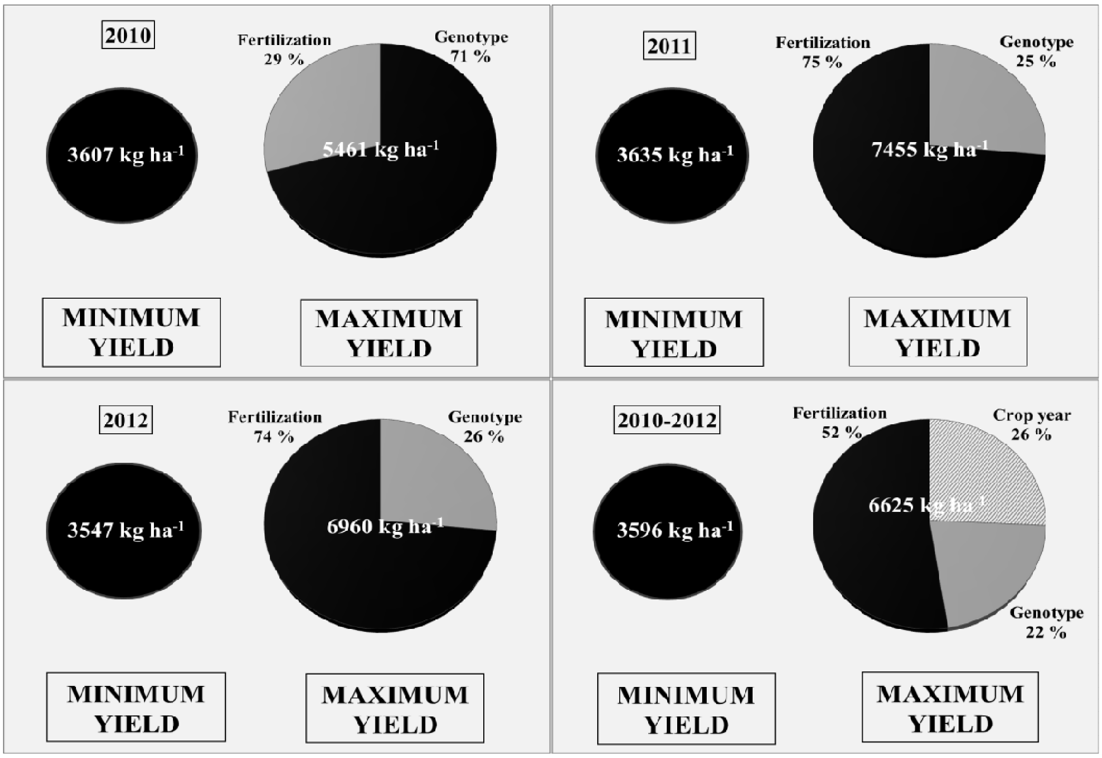

Fig. 2. The significance of the studied factors in determining yield of the winter wheat (Debrecen, 2010-2012)

Evaluating the three crop years together, in the control plots, the average yield was 3596 kg ha^{-1}, the maximum yield in average of the varieties was 6625 kg, which gave 3029 kg ha^{-1} yield increment. The genotype caused 22% (661 kg ha^{-1}), the nutrient supply contributed to 52% (1588 kg ha^{-1}), and the crop year resulted 26% (780 kg ha^{-1}) of production of yield increment. The fact that the three distinct and rich in extreme effects crop year had a slighter influence on production of yield increment shows the good ability of the varieties to adapt. The high percentage of the contribution of nutrient supply to the formation of yield increment shows that in order to achieve high yields, even regardless of the crop year, it is important to ensure adequate supply of nutrients. 26% of contribution of genotypes showed that to gain high yields, good biological base and nutritional response is essential.

Conclusions

The results suggest that genotype and nutrient supply had considerable influence on yield, while the season modified the investigated parameters in significant manner. The large amount of precipitation is the most harmful, compared to the average crop year, varieties achieved 1994 kg ha^{-1} lower yield, and the optimum dose of nutrients was formed at N_{30-60} + PK nutrient levels. During the average year (2011) the varieties produced highest yields at both the control (3635 kg ha^{-1}) and N_{90-150}+PK levels (7455 kg ha^{-1}). The effect of drought could be reduced with proper nutrient treatment, 495 kg ha^{-1} decrease in yield was observed at $N_{120-150}$+PK nutrient level. The optimal dose of fertilizer was determined by amount of precipitation of the crop year. The unfavorable effect of the crop year could be reduced with proper nutrient treatment. In the wet crop year, lower doses of fertilizer cause lower yield increase (1854 kg ha^{-1}). In average crop year, N_{90-150}+PK nutrient doses proved to be optimal (3820 kg ha^{-1}). In the drier crop year, the $N_{120-150}$+PK nutrient dose proved to be optimal to counteract the negative crop year effect. The Genius and Pannonikus varieties have good nutrient utilization ability and fertilizer response, even in spite of varying crop year effects. In the average of the three examined crop year, in the development of yield increment, the genotype took part in 22%, the nutrient supply participated in it up to 52%, and the crop year increased the yield in 26%.

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