Thesis of Doctoral (PhD) Dissertation

EXAMINATION OF THE EFFECTS OF VARIETY SPECIFIC FERTILIZATION ON THE QUANTITY AND QUALITY OF THE WINTER WHEAT YIELD

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1. Introduction, prelude of research

Wheat has the greatest production area in Hungary and globally the sowing territory of wheat was 217 million hectare in 2007. The worldwide significance of wheat cultivation is well demonstrated by the fact that wheat is the third most produced food among the cereal crops. The most important wheat producer countries of the world are: the People's Republic of China, the European Union, the Community of Independent States (CIS), the Republic of India, and the United States of America, theirs common sharing of the global wheat production is 66.8 percent. The importance of wheat production is based on its role as determinant staple food supply for humans and due to the future prognosis this function will be more intensified.

In our country the sowing area of wheat is about 1.0-1.1 million hectare currently. The extensive wheat cultivation period lasted to 1960 can be characterized by 1-1.5 t/ha average yield. In the next period ranged from 1960 to 1990 there was a noticeable improving in the crop results, the average yield growth was 130 kg/ha per year. This tract of time laid the foundation of development of Hungarian wheat production. However, from 1990 subsequently the democratic transformation harvest results show a declining tendency. In the past years the wheat producing sector underwent a considerable change, the coverage of sowing territory decreased, and due to the narrow external and internal market demand the realization of the crop yield was get uncertain, the price gap between agricultural and industrial products widens. Moreover the negative affects of environmental factors (drought, inland inundation) intensified the unfavorable market conditions. Decaying circumstances resulted significant decrease in the quality and quantity of the wheat yield.

Tendencies of average yield and the assurance of crop have notably influence on the future of Hungarian wheat production, moreover very important to follow a quality orientated direction in wheat production. Because of the natural and financial resources are not unlimited the question of proper application of cultivation method and the increasing of average yield in parallel with the decreasing of crop fluctuation have primary importance in either case of site- or variety specific production methods, as is to be expected. From the plant cultivation technologies the nutrient supply has different effects on the quality and quantity of yield in the case of differing genotypes because there are variety specific reactions among dissimilar wheat varieties. Simultaneously, the effect of fertilizing is greatly influenced by the meteorological conditions of the crop year, mainly the amount of precipitation, moreover the soil properties. In the case of a given crop field the best method to moderate the unfavorable effects of different cropyears is the proper choice of varieties show great adaptability to the local ecological conditions and the application of the adequate cultivation method suitable for the chosen genotypes. This procedure demands much more agronomical competence than economic cost. Our most valuable wheat varieties are capable of producing yield with excellent quality and great volume under favorable and unfavorable cultivation circumstances due to their good adaptation capacity.

2. Research objectives

The objectives of my research were to determine the effects of nutrient supply under different doses on the leaf area and photosynthetic activity of 31 different winter wheat varieties via small-plots cultivation experiments. Moreover I examined the shaping of yield quality and quantity of those 31 wheat varieties belong to different ripening class under uniformed agrotechnology in different crop years. The observation was carried out at the Látókép Plant Cultivation Research Site of the Centre for Agricultural Sciences and Engineering of Debrecen University for four years between 2003 and 2007. The soil of the research site was plain and flattened calciferous chernozem with have excellent water holding capacity. The small-plot experiments were set up in split-plot arrangement with four repetitions. In each experimental year we applied the same fertilizer dosage. The gross area of a parcel was 18 m^2 in the split-plot design.

3. Materials and methods

3.1. Winter wheat varieties involved in the experiment

Currently there is an accelerated trend in the changing of wheat varieties and the 31 examined varieties represent a broad range of the Hungarian winter wheat variety assortments. In the experiment we have tested the following wheat varieties: GK Öthalom, Lupus, GK Kapos, Saturnus, Mv Mazurka, Sixtus, Fatima 2, GK Holló, Boszanova, Ukrainka, GK Petur, GK Attila, Mv Emese, Mv Palotás, Mv Verbunkos, Mv Csárdás, Mv Ködmön, Mv Süveges, Mv Suba, GK Memento, GK Talon, Kunhalom, Novalis, Mv Magvas, Mv Walzer, GK Kalász, GK Békés, KG Széphalom, Biotop, GK Csillag, GK Nap. These varieties represent both of the wheat varieties of modern and out-of-date genotypes; moreover these varieties belong to different ripening classes. In our experiments we selected from the genotypes with bread making qualities and varieties with so called corrective quality. Some varieties (i.e. GK Öthalom, Lupus) were tested in each five experimental years but other varieties were examined for shorter periods.

3.2. Weather of the experimental years (*Table 1.*)

3.2.1. Weather of **2002-2003** cropyears

In the crop year of 2003 there were observable weaker vegetative developments of wheat stands, characterized by worse tillering and heading and inappropriate grain filling processes due to the unfavorable weather conditions i.e. long drought periods in the months of autumn, winter, spring and early summer. Besides the long lasting snow-covered terms of winter it was followed by the high rise of temperature without transition and the canicular days in May and June. The average temperature of the cropyear was by 0,9 ^{o}C higher than the normal (6,9 ^{o}C) annual average value. Moreover the average precipitation value was below by 37,1 mm than the normal (400,9 mm) annual average value.

3.2.2. Weather of **2003-2004** cropyears

The autumn of 2004 crop year were favorable in the case of weather. Due to the cold and the average precipitation weather in spring the vegetative development of crop stands were excellent. In the period of grain filling there were average rainfall and temperature weather. The average temperature of the cropyear was by 1,2 ^{o}C higher than the normal (6,9 ^{o}C) annual average value. Moreover the average precipitation value was below by 117,8 mm than the normal (400,9 mm) annual average value.

3.2.3. Weather of **2004-2005** cropyears

The autumn and early winter weather was favorable in the 2005 crop year. The vigorous vegetative development of crop stands were promoted by the optimal precipitation values in the months of April, May and June although spring came rather late after the harsh winter period. The lodging of stands occurred in high rate and rather early duet to the enormous amount of vegetative mass. The average temperature of the cropyear was by 1,9 ^{o}C higher than the normal (6,9 ^{o}C) annual average value. Moreover the average precipitation value was below by 108,8 mm than the normal (400,9 mm) annual average value.

3.2.4. Weather of **2005-2006** cropyears

The autumn and winter half cropyear of 2006 was characterized by cold and dry weather conditions and lasted to the second half of March. The productive head number values and the rate of tillering fell behind the average values because of the spring came late. There were rapid warming up and copious rainfall in April but the weather of May was typical. The cold and rainy weather from the end of May to the beginning of June was followed by a long drought period lasted to the harvesting time. The average temperature of the cropyear was by 1,3 ^{o}C higher than the normal (6,9 ^{o}C) annual average value. Moreover the average precipitation value was below by 106,4 mm than the normal (400,9 mm) annual average value.

3.2.5. Weather of **2006-2007** cropyears

The autumn term of the vegetative period in 2007 was unfavorable in meteorological aspects because of the weather was dry and warmer than average. Lack of precipitation was characteristic of the spring months too, in consequence of warm weather the development of crop stands were rapid and the vegetation period was shorter than in general. The average temperature of the cropyear was by 4,4 ^{o}C higher than the normal (6,9 ^{o}C) annual average value. Moreover the average precipitation value was below by 152,6 mm than the normal (400,9 mm) annual average value.

Table 1. **The fluctuation of precipitation and temperature**

(Debrecen, 2003-2007)

Month	**Quantity of precipitation (mm)**						**Average temperaturet (^{0}C)**					
	2002/ 2003	2003/ 2004	2004/ 2005	2005/ 2006	2006/ 2007	**30 year average**	2002/ 2003	2003/ 2004	2004/ 2005	2005/ 2006	2006/ 2007	**30 year average**
IX.	45,9	90,0	38,5	7,0	22,9	**30,8**	9,2	7,9	11,1	10,8	11,3	**10,3**
X.	29,9	21,7	63,5	12,6	9,2	**45,2**	6,0	5,9	4,9	3,5	6,2	**4,5**
XII.	27,5	20,8	33,7	83,5	5,0	**43,5**	-1,8	-0,5	0,9	0,2	2,2	**-0,2**
I.	36,6	37,2	18,2	22,5	23,9	**37,0**	-3,3	-3,3	-0,9	-3,4	3,7	**-2,6**
II.	39,4	41,6	40,6	44,2	53,2	**30,2**	-6,1	-0,7	3,7	-1,4	4,1	**0,2**
III.	9,7	46,5	10,5	79,0	14,0	**33,5**	2,9	4,8	2,2	3,2	9,1	**5,0**
IV.	13,7	40,0	74,9	92,3	3,6	**42,4**	9,2	11,4	10,8	12,1	12,6	**10,7**
V.	54,4	17,0	75,8	58,3	54,0	**58,8**	19,1	14,8	16,2	15,4	18,4	**15,8**
VI.	22,2	61,7	54,3	77,1	22,8	**79,5**	21,3	19,3	18,4	18,6	22,2	**18,7**
VII.	84,5	142,2	99,7	30,8	39,7	**65,7**	21,3	21,1	21,1	23,2	23,3	**20,3**
Sum-total averge	*363,8*	*518,7*	*509,7*	*507,3*	*248,3*	*400,9*	*7,8*	*8,1*	*8,8*	*8,2*	*11,3*	*6,9*
Differencies from 30 year	**-37,1**	**117,8**	**108,8**	**106,4**	**-152,6**	**---**	**0,9**	**1,2**	**1,9**	**1,3**	**4,4**	**---**

3.3. Soil of the experimental area

The soil of the experimental area was plain and flattened calciferous chernozem. On the basis of values of physical parameters of soil the examination area is classified as adobe soil. The soil specific plasticity index (K_A) was 43, the pH value was nearly neutral (pH_{KCl}=6.46). The phosphorus content of the soil was medium (the value of AL-soluble P_2O_5 was 133 mg/kg), the degree of potassium supply was fairly-good (the value of AL-soluble K_2O was 240 mg/kg). The humus content of the soil was medium and the thickness of humus layer was about 80 cm. On the aspect of water balance the soil was characterized with excellent water uptake and holding capacity. The proportion of the disponible water was 50% of the collection of water. The level of ground water was below the soil surface with 3-5 m and did not rise over 2 m in either case of rainy years.

3.4. Agrotechniques applied in the experiment

The long-term experiment was carried out in the autumn of 1983. After the so called blind-experiment of the first year, we carried out and evaluate the results of standard experiments from the autumn of 1984. In conformity with the demands of the long-term experiment have lasted for 25 years we applied the appropriate dose of fertilizer in accordance with the fertilization program in every year. The application of the equivalent amount of fertilizer in the adequate range of doses forms the bases and essence of variety testing method of Bocz. The small-plot experiments were set up in strip arrangement with four repetitions in split-plot design. We applied the same fertilizer doses in every experimental year (*Table 2.*). The forecrop was sweet corn in each experimental year. In all examined year we crushed the stem of the maize after harvesting and work it into the soil in the same way. We measured, carried and spread of the fertilizer by hand in each of the small-plot parcel (*Table 3.*).

Table 2. **The applied fertilizer doses in the experiment**

(Debrecen, 2003-2007)

Treatment	**Active agents (kg/ha)**			
	N	**P_2O_5**	**K_2O**	**Sum total active agent:**
Ø	0	0	0	0
1	30	22,5	26,5	79
2	60	45	53	158
3	90	67,5	79,5	237
4	120	90	106	316
5	150	112,5	132,5	395

Table 3. **Applied agrotechnical methods in the experiments**

(Debrecen, 2003-2007)

Agrotechnical methods:	***2003***	***2004***	***2005***	***2006***	***2007***
Fertilizer doses in autumn	100% PK 50% N (27.08. 2002.)	100% PK 50% N (22. 08. 2003.)	100% PK 50% N (05. 10. 2004.)	100% PK 50% N (04. 10. 2005.)	100% PK 50% N (26. 09.2006.)
Fertilizer doses in springn	50% N (25. 03. 2003.)	50% N (18. 03. 2004.)	50% N (01. 04. 2005.)	50% N (03. 04. 2006.)	50% N (07. 03. 2007.)
Sowings	05. 10. 2002. Wintersteiger sowing-machine	13. 10. 2003. Wintersteiger sowing-machine	12. 10. 2004. Wintersteiger sowing-machine	07. 10. 2005. Sulky sowing-machine	07. 10. 2006. Sulky sowing-machine
Weed control	26. 04. 2003. Sekator 0,3 kg/ha	17. 04. 2004. Sekator 0,3 kg/ha	24. 04. 2005. Sekator 0,3 kg/ha	30. 04. 2006 Solar 0,2 l/ha+ Duplosan DP 1,5 l/ha+ Granstar 5 g/ha	28. 03. 2007. Sekator 0,15 l/ha
Fungicides	06. 05. 2003. Falcon 460 EC 0,6 l/ha –20. 06. 2003. Falcon 460 EC 0,8 l/ha	04. 05. 2004. Falcon 460 EC 0,6 l/ha –21. 06. 2004. Falcon 460 EC 0,8 l/ha	06. 05. 2005. Falcon 460 EC 0,6 l/ha –29. 06. 2005. Falcon 460 EC 0,8 l/ha	06. 05. 2006. Falcon 460 EC 0,6 l/ha –26. 06. 2005. Falcon 460 EC 0,8 l/ha	13. 04. 2007. Falcon 460 EC 0,6 l/ha –14. 05. 2007. Falcon 460 EC 0,8 l/ha
Harvest	02. 07. 2003. Sampo combine	13. 07. 2004. Sampo combine	22-25. 07. 2005. Sampo combine	17. 07. 2006. Sampo combine	25. 06. 2007. Sampo combine

3.5. Other examinations

Photosynthetic activity was measured with a portable LI 6400 photosynthesis measuring instrument, while leaf area was measured with LAI 2000 leaf area measurer. The physiological examination of the plants we carried out in both experimental years under three nutrient level (control, N_{60}+PK and N_{120}+PK) at three times in each cropyear (19th of April, 10th of May and 10th of June.) In the case of 2007 the date of the measurements were 28th of March, 26th of April and 23rd of May. We analyzed and evaluate the data of experimental results with the SPSS 13.0 statistical software package. The accuracy of the statistical analysis were given at the level of $LSD_{5\%}$ according to the method of Sváb (1981).

The measurements of quality parameters were performed at the Institute for Food sciences, Quality assurance and Microbiology, UD Centre for Agricultural Sciences and Engineering. The values of wetness, wet gluten contents, gluten elasticity values, valorigraph index and the Hagberg Falling Number were determined according to the Hungarian standards (MSz 6367-3:1983, MSz ISO 5531: 1993, MSz 6369-5: 1987, MSz ISO 5530-3:1994 and the MSz ISO 3093: 1995, respectively).

The results were evaluated with analysis of variance, linear regression analysis, analysis of Kang's stability and Pearson's correlation analysis.

4. Results, main statements of dissertation

4.1. The effects of fertilization and variety-specific interaction on the photosynthetic activity

We examined the effects of nutrient supply on the photosynthetic activity of winter wheat varieties. We carried out our measures for three times (March, May and June) in the vegetation periods of 2006 and 2007 in the case of two winter wheat varieties (GK Öthalom and Mv Mazurka) at three levels of nutrient dosage (control, N_{60}+PK and N_{120}+PK). The values of net photosynthetic activity were lower in 2007 than in 2006. We measured the highest value of net photosynthetic activity on the second measuring date (May) in case of both varieties (32.5 µmol CO_2 sec^{-1} GK Öthalom at control nutrient level and 36.1 µmol CO_2 sec^{-1} Mv Mazurka at N_{120}+PK) in 2006. Since the third measuring date (June) the rate of growing was lower at the highest nutrient level probably due to the changed weather conditions. In the crop year of 2007 from the first measure (March) the weak decreasing of values of net photosynthetic activity was observed (27.2 µmol CO_2 sec^{-1} GK Öthalom at N_{120}+PK and 29.6 µmol CO_2 sec^{-1} Mv Mazurka at N_{60}+PK) due to the drought and the lack of precipitation.

In both experimental crop years the results of leaf area index (LAI) analysis proved the strong varieties specificity in the case of examined genotypes. Among the examined varieties we measured the highest values of LAI (4.91 m^2m^2) in the case of Lupus on the third measuring date

(June) in 2006. In the next crop year (2007) the highest value of LAI (4.48 m^2m^2) was measured in the case of Mv Mazurka in June. Since May of 2007 the volumes of leaf area were greater in the highest (N_{120}+PK) nutrient dose (significantly affected by the fertilization and the crop year effects) moreover we found significant difference between the values of LAI at different nutrient treatments. We found strong positive correlation (*Table 4.)* too, (with applying Pearson's correlation method) and with this result we proved the existence of significant connection between values of LAI and the measure of yield. The volume of the leaf area had effected on the volume dynamics of dry matter formation.

Table 4. **Evaluation of the effects of agrotechnical parameters and physiological elements withy Pearson's correlation analysis in the case of winter wheat cultivation**
(Debrecen, 2006-2007)

2006	***Yield***	***LAI1***	***LAI2***	***LAI3***
Fertilization	0,879**	0,604*	0,959**	0,938**
Yield	1	0,461	0,924**	0,868**
2007				
Fertilization	0,951**	0,878**	0,965**	0,972**
Yield	1	0,851**	0,926**	0,946**

**correlation is significant on P=1%probability level
*correlation is significant on P=5% probability level

4.2. The effects of fertilization on the yield of winter wheat varieties between 2003 and 2007

On the results of fertilization experiments carried out from 2003 to 2007. in the Hajdúság region on chernozem soil the following winter wheat varieties could be characterized with excellent natural nutrient utilization efficiency: GK Holló, GK Attila, Kunhalom, Lupus and Biotop. Theirs yield ranged from 4143 to 5825 kg ha^{-1} in control (non-fertilized) treatment. On the results of five year experiment data the greatest yield were produced by GK Holló, Ukrainka, Fatima 2, Sixtus, GK Kapos, GK Kalász and GK Attila varieties (harvest results were between 7532-9442 kg ha^{-1}). Due to the effects of higher fertilizer doses we observed excellent yield growth in the case of Fatima 2, Ukrainka, Mv Ködmön, Mv Süveges, Mv Mazurka and GK Kapos varieties. We detected 4076-5344 kg ha^{-1} yield surplus during the five year experiment. On the results of complex evaluation of examined parameters the GK Holló, Boszanova, Fatima 2, Ukrainka, GK Kapos, GK Attila, Gk Kalász, Sixtus, GK Békés and the GK Csillag varieties could be characterized with excellent yield efficiency and fertilizer response on the average of several years.

The effects on nutrient supply on the yield were very diverse due to the modifying effects of different genotypes and cropyears (*Table 5.*). Owing to fertilization the surplus yield was 3200 kg ha^{-1} on the basis of average yields of 31 examined wheat varieties and cropyears on chernozem soil in the Hajdúság region. In the case of favorable ecological (cropyear) circumstances the effects of genetically determined differences among varieties were more explicit. The difference in fertilization yield surplus varied 380-1650 kg ha^{-1} in the crop year of 2003 characterized by unfavorable weather conditions (the key factor was the amount and occurrence of precipitation). In contrast with 2003 the weather was favorable in 2004 resulted greater fertilization surplus yield (3200-5100 kg ha^{-1}). We observed that was greater the effects (positive or negative direction) of given cropyear on the yield in the case of favorable environmental terms. The utilization of fertilizers (yield-surplus/1 kg NPK) varied broad range during the five years of experiment. The fertilizer-specific yield surplus varied between 4,52 and 29,25 kg/l kg NPK.

Table 5. **Effects of fertilization on the yield surplus in the average of varieties**
(Debrecen, 2003-2007)

Year	**Control (kg ha^{-1})**	**Maximum yield (kg ha^{-1})**	**Fertilizer utilization capacity (kg ha^{-1})**	**NPK dose of max. yield**	**Specific surplus of max. yield (kg)**
2003	3447	4387	940	N_{60-90}+PK	4,52
2004	3447	8574	5127	N_{60}+PK	24,44
2005	4601	8098	3497	$N_{30-60-90}$+PK	29,25
2006	3871	6944	3073	$N_{120-150}$+PK	9,11
2007	3308	6856	3548	$N_{90-120-150}$+PK	11,65
Average (5 year)	**3735**	**6972**	**3237**	**N_{90}+PK**	**15,79**

We analyzed the values of cropyields in the case of four varieties (GK Öthalom, Lupus, GK Kapos and Saturnus) to evaluation of variety specific fertilizer responses in the years between 2004 and 2007. (*Figure 1.).* We found significant differences between the natural nutrient utilization efficiency, the utilization of genetic yield ability (maximum yield in agroecological optimum fertilizer treatment), the utilization of fertilizers (yield-surplus/1 kg NPK) and the optimal fertilizer demand of genotype (NPK dose of maximum yield) of the examined varieties, but these parameters were significantly modified by the effects of a given cropyear without any influence of genotypes. Although the examined four cropyears were very different in the case of weather conditions (2004 was very favorable, 2005 was favorable than the average, 2006 was average and 2007 was less favorable than the average) the GK Kapos variety showed in the case of three occasion from the examined four cropyear great yields (the yield was 8709 kg ha^{-1} in 2004, 8596 in 2005 and 4211 in 2007) and its fertilizer response was excellent too (3879 kg ha^{-1} in 2004, 3865 in 2005 and 4211 in 2007).

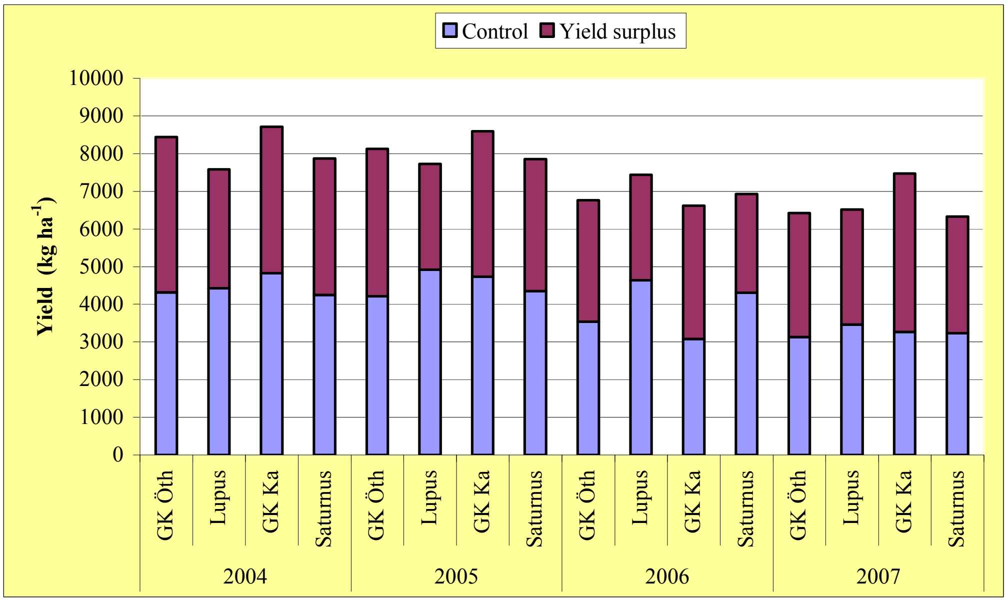

Figure 1. **The variety-specific fertilizer response of winter wheat varieties** (Debrecen, 2004-2007)

4.3. Classification of winter wheat varieties on the basis of their fertilizer responses

Based on the examination of wheat varieties on the aspects of their natural nutrient utilization and fertilizer response we observed that under the same agrotechnical practice but strongly different climatic conditions these parameters varied differently. From the examined varieties the GK Holló achieved outstanding values of natural nutrient utilization capacity (4080 kg ha^{-1} in 2003 and 5375 kg ha^{-1} in 2004) and its fertilizer response (the maximum yield were 5352 kg ha^{-1} in 2003 and 9059 kg ha^{-1} in 2004) although the weather conditions were different in these years. Similarly in 2006 and 2007 the weather was different but the GK Békés and Sixtus varieties showed excellent natural nutrient utilization capacity (in the case of GK Békés 4120 and 3601 kg ha^{-1} and values of Sixtus were 4486 and 3771 kg ha^{-1} in 2006 and 2007, respectively) and fertilizer response (the maximum yield were in the case of GK Békés 6983 and 7330 kg ha^{-1} and values of Sixtus were 7842 and 6883 kg ha^{-1} in 2006 and 2007, respectively) in both years. On the average yield result of four examined varieties we stated that the out-of-date genotypes of GK Öthalom and Saturnus showed bad natural nutrient utilization capacity (3801 and 4033 kg ha^{-1} in the case of GK Öthalom and Saturnus, respectively) and weak fertilizer response (maximum yield were 7438 and 7245 kg ha^{-1} in the case of GK Öthalom and Saturnus, respectively) in the crop year of 2004-2007. On the contrary, the GK Kapos one of the modern wheat genotypes beside average natural nutrient utilization capacity (3976 kg ha^{-1}) was characterized by excellent fertilizer response (maximum yield was 7850 kg ha^{-1}). The Lupus variety showed excellent natural nutrient utilization capacity (4360 kg ha^{-1}) and moderate fertilizer response (the maximum yield was 7316 kg ha^{-1}). We classified into four different groups the examined varieties based on the natural nutrient utilization capacity. The results of the classification are illustrated in the coordinate system of the *figure2*.

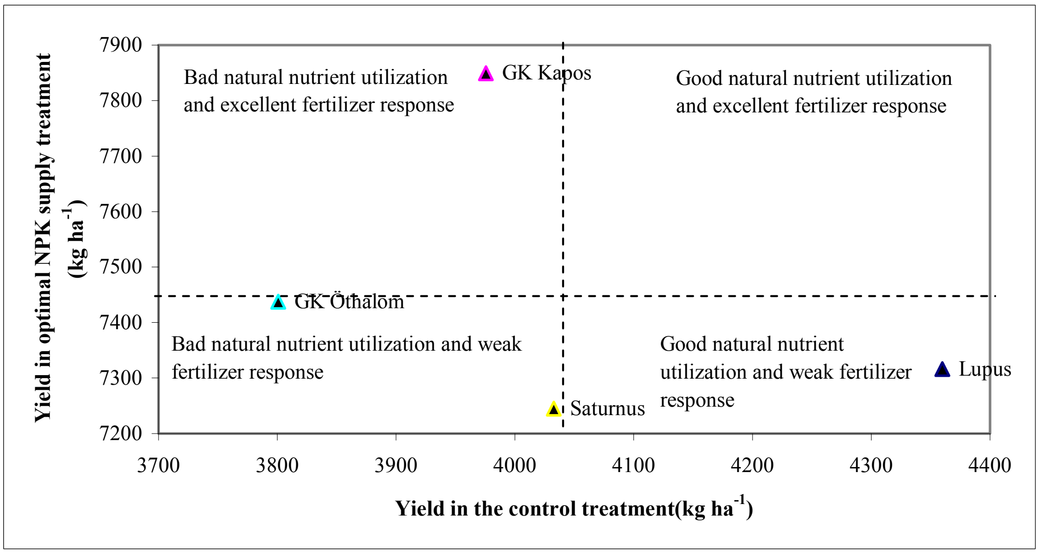

Figure 2. **Relationships between the yield properties of the examined four winter wheat varieties in control and optimal-NPK supplying treatments The segmented lines illustrate the average values of yield of a given treatments**
(Debrecen, 2004-2007)

4.4. Determination of fertilizer demand of winter wheat genotype (N_{opt} + PK) with application of regression analysis

The results of regression analysis proved that there were significant differences between the tested varieties in the demand values of agroecological optimal NPK doses in relation with the year effect. In the average of five years, the optimal nutrient demand of examined genotypes varied between the following values 84-118 kg ha^{-1} of N, 64-86 kg ha^{-1} of P_2O_5 and 75-100 kg ha^{-1} in the case of K_2O. In 2006 under weaker environmental conditions the values of the optimal NPK doses of the maximum yield were shifted toward the higher levels – varied in wide range of values (N 102-153 kg ha^{-1}, P_2O_5 77-101 kg ha^{-1} and K_2O 90-120 kg ha^{-1}) resultanted from the favorable and unfavorable conditions. In the case of each examined variety the most intensive yield increment was obtained at these nutrient supply levels. Moreover we suppose that the GK Öthalom, GK Attila and Saturnus varieties would have reacted with more increased yield if we had applied higher dose of fertilizer. In a given year the Sixtus, GK Kalász, GK Ati, Lupus, GK Petur and the KG Széphalom varieties produced yield more than 7000 kg ha^{-1}. On the contrary, due to the improving environmental conditions (the cropyear of 2004 was characterized by very favorable amount and distribution of precipitation), the agroecologicaly optimal NPK demand was at lower level. The optimal values in the case of N, P_2O_5 and K_2O varied between 87-99, 65-74 and 77-85 kg ha^{-1} respectively.

4.5. The interactive effects of nutrient supply and variety-specific reaction on the yield stability

In the years of 2004-2007. we studied the yield stability (*Figure 3.)* of four winter wheat varieties (GK Öthalom, Lupus, GK Kapos and Saturnus). Among of the examined varieties the Lupus was the most stable, it means that under weaker environmental conditions its yield was higher than the yield of the other varieties at the control level of fertilizer treatments. But the maximum yield of this variety was considerably lower than the other varieties in the case of favorable environmental conditions. The variety of GK Kapos can be considered as the most instable and sensitive. Under unfavorable environmental conditions its yield was lower (3076 kg ha^{-1} in 2006) than the yield of environmental average (4000 kg ha^{-1}), but with the improvement of the environmental conditions (environmental average were 5500-6000 kg ha^{-1}) its yield was outstandingly high (8709 kg ha^{-1}) in 2006. On the basis of these results it can be supposed that there is weak negative correlation between the quantity and the stability of yield.

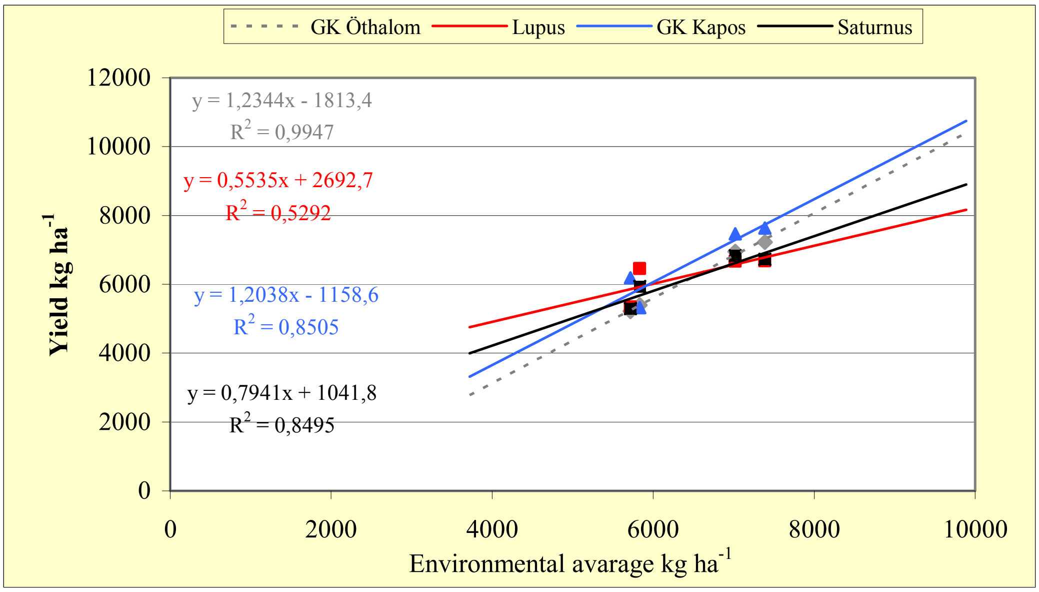

Figure 3. **Trends in the yield stability of winter wheat varieties**
(Debrecen, 2004-2007)

The results of the Kang's yield stability analysis of the fertilizer treatments (*Figure 4.)* proved that the most stable but lowest yield (2500-4000 kg ha^{-1}) was obtained in the control treatment. The greatest increase of the yield was observed in the N_{60}+PK treatments under improving environmental conditions (7000-8000 kg ha^{-1}), while the N_{90}+PK treatment resulted the largest yield increment (5500 kg ha^{-1}) in the case of less favorable environmental conditions. The maximal fertilizer dosage increased the yield to a higher extent under weaker environmental conditions; while in the case of advancing circumstances the greatest yield was observed in the N_{60}+PK treatments.

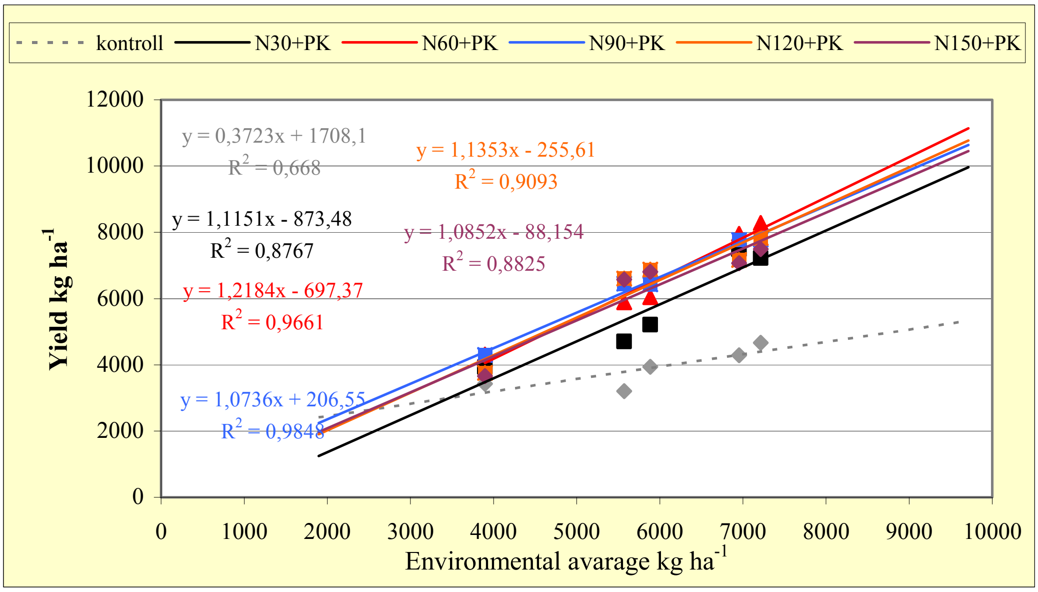

Figure 4. **Effects of fertilizer treatments on the yield stability of winter wheat varieties** (Debrecen, 2003-2007)

4.6. Effects of fertilization and genotypes on the quality of the yield between 2003 and 2007.

From the examined quality parameters the wet gluten contents of genotypes was determined markedly by the nutrient supply only. In the case of other parameters the quality improve effects of fertilization was moderate on the varieties. Analyzed the wet gluten contents of the examined varieties in the average of five years we observed that the average gluten contents of the varieties increased continuously as a result of fertilization but until it had reached the N_{150}+PK fertilizer level (*Figure 5.)*. In 2006 the maximum value of gluten contents in the average of varieties was 40.03%. In 2003 the wet gluten contents increased (values varied between 19.74-42.95%) as a result of fertilization in the case of all the examined varieties. In 2004 the average gluten contents of the examined varieties ranged between 23.67 and 41.55%. In 2005 the values of examined parameters varied between 17.71 and 43.44%. The values of wet gluten contents ranged between 28.29 and 46.50% depending on the nutrient level in the 2006 cropyear. In 2007 the gluten contents of the examined varieties varied between 20.22 and 40.27% depending on the applied nutrient levels.

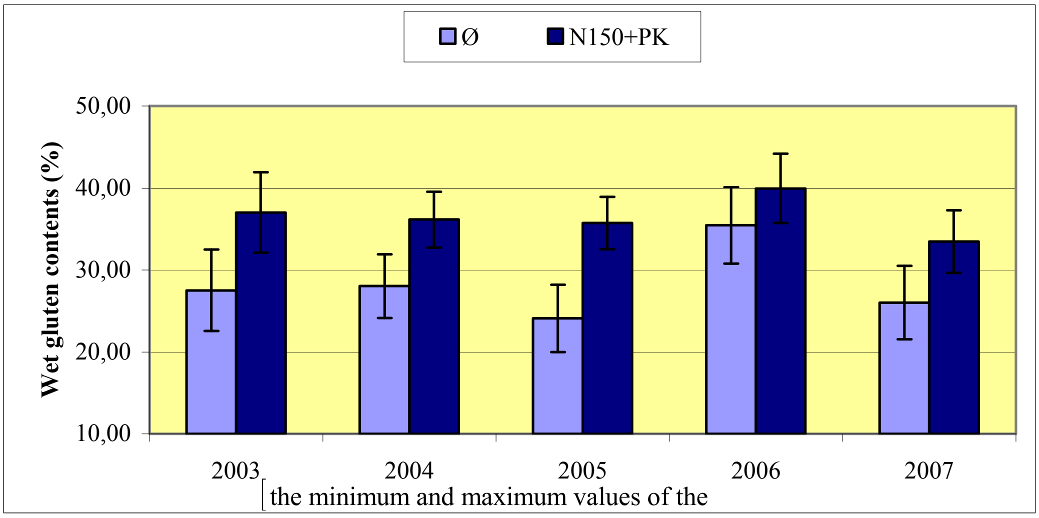

Figure 5. **The effects of nutrient supply on the wet gluten contents of winter wheat in the average of the examined varieties** (Debrecen, 2003-2007)

In the average of varieties (*Figure 6.)* the nutrient supply had the least effect on the changing of valorigraph index (there were 11.44 in the average of five years). During our experiments in the case of each variety optimal nutrition level could be found at every level of fertilizer dosage, the variety-specific response of genotypes were significant. In 2003 the values of valorigarph index varied between 11.50 and 58.75. We measured greater values of the index (55-60) than average in the case of GK Öthalom, Mv Palotás, Lupus and the Ukrainka varieties. The examined quality parameter ranged between 41.50 and 77.00 in 2004. The Mv Suba, Lupus and the Saturnus varieties showed values of valorigraph index about 70. We measured outstanding values (31.95-81.50) during our experiment in 2005. Based on their high valorigaph index the Sixtus, Lupus, GK Memento, GK Talon, Novalis, Mv Mazurka and the Saturnus varieties were ranked in the A_2 quality category. In 2006 the values of valorigraph index ranged between 45.45 and 72.18. The Saturnus, Mv Emese and the GK Kalász varieties reached the values of valorigraph index over 70. We measured values varied between 40.43 and 84.30 in 2007. The KG Széphalom, Mv Mazurka, Mv Suba, Biotop, GK Békés and the Saturnus varieties showed excellent, over 70 values of valorigraph index.

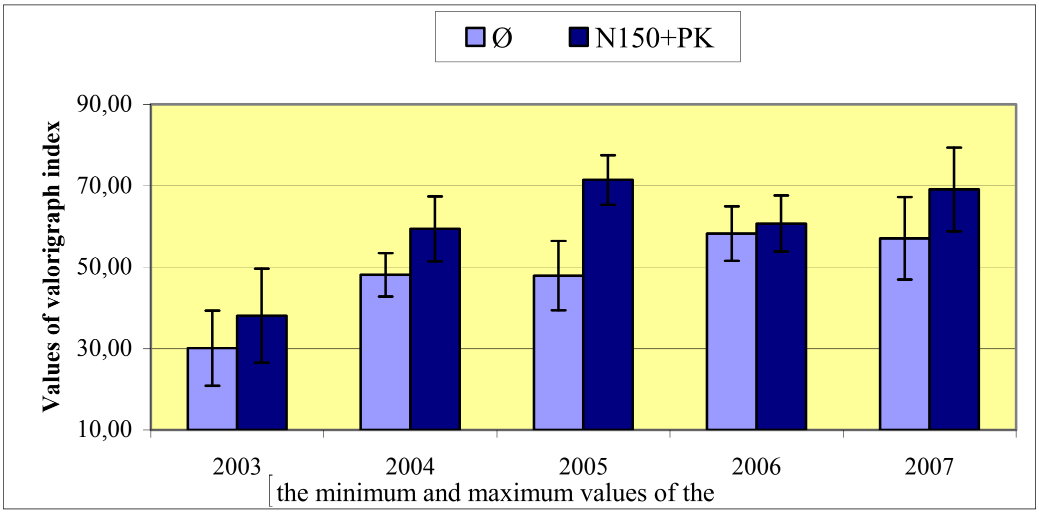

Figure 6. **Effects of fertilization on the valorigraph index of winter wheat in the average of varieties** (Debrecen, 2003-2007)

The gluten elasticity increased with parallel the increasing fertilizer doses (up to the $N_{120-150}$+PK levels). The values of gluten elasticity varied between 3.52 and 12.04 mm in the average of the varieties (*Figure 7.).*

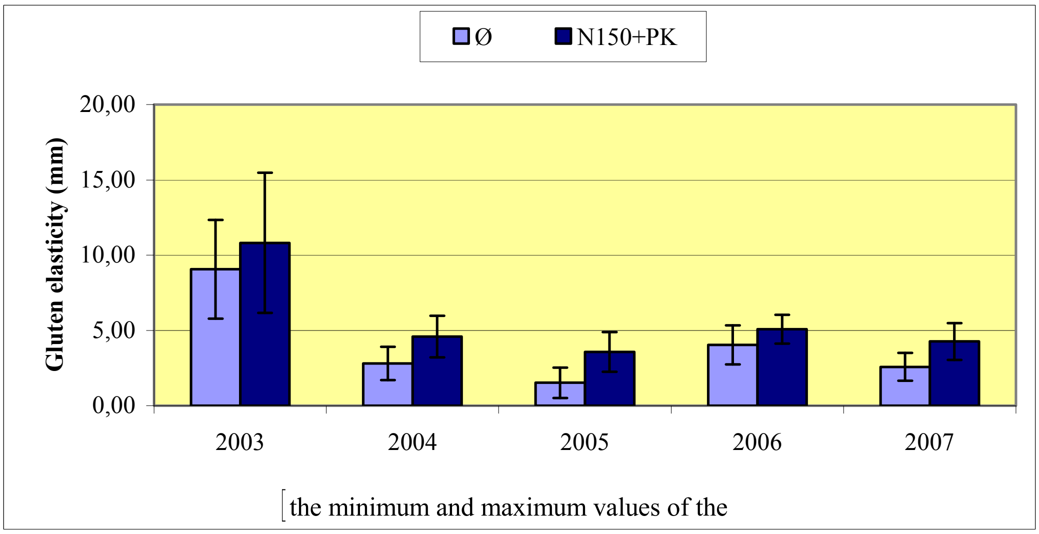

Figure 7. **The effects of nutrient supply on the gluten elasticity values (mm) of winter wheat in the average of varieties** (Debrecen, 2003-2007)

In 2003 due to the negative modifying effect of drought the measure of gluten elasticity varied between 4.41 and 20.00 mm. The greater values were observable at the control and the lower fertilizer levels. In 2004 we measured very good elasticity values (1.75-7.75 mm) in the majority case of varieties at the control fertilizer level depending on the variety and fertilizer level. In 2005 the measure of gluten elasticity varied between 1.00 and 6.25 mm. In 2006 as compared with the previous year there were measured a little higher gluten elasticity (varied between 2.13 and 6.88 mm). In 2007 the gluten elasticity varied between 1.25 and 6.25 mm. Each of the examined variety was characterized by good values of gluten elasticity depending on the fertilizer level.

In the case of the Hagberg falling number (HFN) we observed the modifying effects of the interaction between climatic factors and the fertilization (*Figure 8.)*. The application of higher fertilizer doses were followed by the increments of HFN in the majority case of the examined varieties. This increasing lasted to the $N_{120\text{-}150}$+PK fertilizer treatments. In the cropyear of 2005 were measured the lowest values of HFN (302-330 s in the average of the varieties) in our experiment. In 2003 the HFN values varied between 305 and 442 s, there were observable significant differences between the varieties. In 2004 the maximal values of HFN were higher than in the year before, varied between 277 and 484 s. In 2005 there were significant differences between the values of the HFN of varieties, the values varied between 132 and 429 s. We measured lower values in the averages of varieties and fertilizer treatments than in the previous year. In 2006 we measured very high (317-486 s) HFN values. In 2007 the HFN values varied between 302 and 495 s. From the aspects of the average of varieties the increments of HFN values was dominant process as a result of increasing fertilizer dosage.

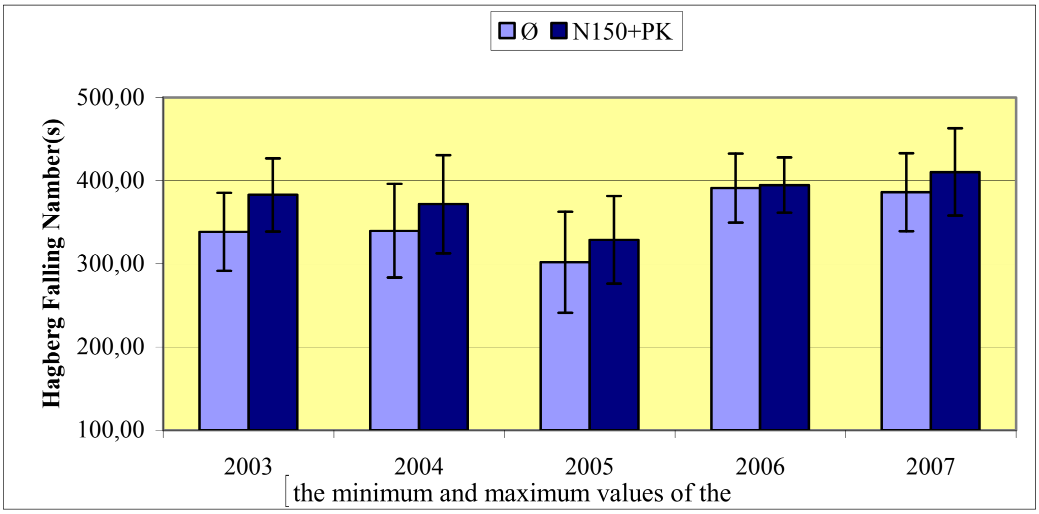

Figure 8. **The effects of fertilization on the values of Hagberg Falling Number (s) in the average of varieties** (Debrecen, 2003-2007)

In the process of variety specific fertilizer response determination there were significant differences between the examined varieties in the case of quality parameters. In the average of examination years we observed that the Saturnus variety had the highest values of wet gluten percents (39.51%). The GK Öthalom showed slight fertilizer response (that values were 28.29% in the control and 31.87% in the N_{150}+PK treatment in 2006) but in the case of GK Kapos variety we observed very expressive fertilizer response (that values were 30.73% in the control and 38.56% in the N_{150}+PK treatment) in 2006.

The effect of species-specific effect was very well detected in the analysis of valorigarph index of wheat varieties. Among the varieties the Lupus and the Saturnus varieties were characterized by over 70 index values (in 2005, 2006 and 2007). The GK Kapos variety had the lowest values of valorigarph index (it was 50.25 in the treatment of N_{150}+PK) in 2004. The GK Kapos variety is a suitable example for the solving of the very complex problem of the strong negative correlation between the quality and quantity parameters because this variety had excellent yield producing ability and fertilizer response but on the basis of its baking quality this variety should have been ranked in the class of milling quality varieties.

The varying of the values of Hagberg Falling Number was affected not so much by the different fertilizer levels as the weather of different cropyears. In the case of GK Kapos and Saturnus varieties we observed excellent HFN values (462 and 448 s respectively) not only in the treatments of higher fertilizer levels but also in the lower treatment (N_{60}+PK) in the each cropyear of 2004, 2006 and 2007 too.

We proved that in the case of those varieties (i.e. Saturnus) which were determined genetically to produce good quality the baking quality showed improvements as a result of appropriate nutrient supply. But the case of varieties represented weaker baking quality the increments of wet gluten contents were not combined with the considerable improvements of the other baking quality parameters (i.e. valorigraph index, Hagberg Falling Number).

4.7. The effects of nutrient supply and the differences between genotypes on the quality stability

Our experimental results proved that due to the increasing nutrient supply there were observable distinct improvements and increments in the case of four examined quality parameters. The quality stability was different in each case of quality parameters. The results of stability analysis of the fertilizer treatments proved that the most stable wet gluten content values were obtained in the N_{150}+PK treatment in the cropyears between 2003 and 2007 under favourable (40%) and less favourable environmental conditions (10%).

The greatest stability was observed in the case of gluten elasticity values at the maximal fertilizer level and under improving environmental conditions the N_{120}+PK treatment has the greatest effects on the increments of elasticity values (5.00 mm). On the contrary just slight influence of the control treatment was detectable on the gluten elasticity values.

In the case of valoriograph index values the greatest stability was observed in the control treatment but the increments of index values were minor. Under unfavorable environmental conditions (the values of the valoriograph index number were about 40) the greatest increments of index values was observed in the lower, N_{90}+PK treatments. On the contrary under improving environmental conditions we observed intensive increase of index values in the stands which were supplied with higher doses of nutrients ($N_{120-150}$+PK) the values of valoriograph index number were about 70.

Under unfavorable environmental conditions the values of Hagberg Falling Number were the lowest in the control treatment but the HFN values showed increasing tendency under improving environmental conditionas. We measured the greatest increments of HFN values in the N_{60}+PK treatment moreover due to the improvement conditions there were detected further intensive increment of values in the N_{150}+PK treatment (the values of HFN were over 350 s).

4.8. Examination of the interaction between the agrotechnical parameters, yield quality and climatic conditions by correlation analysis

We applied Pearson's correlation analysis to evaluate the interaction between the climatic conditions, the quantity of the yield and the quality parameters (wet gluten content, gluten spreading value, valorigraph index and the Hagberg Falling Number). We found strong positive correlation (0,616**) between the quantity of the yield and the nutrient supply. The amount of spring precipitation values were the greatest positive effect (0,738**) on the quantity of the yield. We detected positive correlation (0,551**) between the average spring air temperature and the amount of the yield, but the average air temperature values of early spring were significantly negative (-0,797**) effect on the yield. The measure of nutrient supply was significantly positive influence on all of the examined quality parameters. We found very strong positive correlation (0,708**) between the fertilization and the wet gluten content. Moreover, in the case of valoriograph index (0,538**), and the gluten spreading value (0,662**) showed strong correlation with the applied fertilization levels. The correlation analysis proved that the strong negative connection (-0,702**) between the average spring air temperature and the wet gluten content. The temperature of early summer had the most negative (-0,690**) effect on the valoriograph index, while the correlation was positive (0,578**) with the amount of cropyear precipitation values. From the meteorological parameters, the air temperature value of early summer had beneficial effects (0,741**) on the gluten spreading values in the case of examined wheat species.

Our experimental results proved that by using appropriate fertilization of winter wheat attached to variety-specific fertilizer demands increased not only the amount and the stability of yield but there were observed significant increments of the yield quality and the stability of yield. Due to the increased fertilizer doses the wet gluten contents of winter wheat significantly increased, the values of gluten elasticity were affected slightly, the values of valoriograph index and the Hagberg Falling Number were increased moderately.

5. New scientific results

We examined the effects of incremental fertilizer doses on the leaf area and photosynthetic activity of 31 different winter wheat varieties via small-plots cultivation experiments between 2003 and 2007 crop years on chernozem soil in the region of Hajdúság. Moreover we examined the shaping of yield quality and quantity of those 31 wheat varieties belong to different ripening class under uniformed agrotechnology in different crop years. On the basis of the results of five experimental years we conclude the following new scientific results.

5.1. The rate of photosynthetic activity was affected by the crop year effects and there were significant effects of the surplus nutrient content of the fertilizer which was applied in the experiments on the values of photosynthetic assimilates. We measured the highest value of net photosynthetic activity on the second measuring date (May) in case of both varieties (32.5 µmol CO_2 sec^{-1} GK Öthalom at control nutrient level and 36.1 µmol CO_2 sec^{-1} Mv Mazurka at N_{120}+PK) in 2006. In the crop year of 2007 from the first measure (March) the weak decreasing of values of net photosynthetic activity was observed (27.2 µmol CO_2 sec^{-1} GK Öthalom at N_{120}+PK and 29.6 µmol CO_2 sec^{-1} Mv Mazurka at N_{60}+PK) due to the drought and the lack of precipitation. The results of leaf area index (LAI) analysis proved the strong varieties specificity in the case of examined genotypes. This relationship was significantly affected by the fertilization and the crop year effect. We proved the existence of significant and strong connection between values of LAI and the measure of yield.

5.2. The yield results of our fertilization experiments carried out on chernozem soil in the Hajdúság region from 2003 to 2007 were varied in great range due to the different weather conditions. On the basis of our experimental results in the favorable cropyears – in the average of varieties – we reached around 7000 kg ha^{-1} yield values (the yield was 7389 kg ha^{-1} in 2004 and 7020 kg ha^{-1} in 2005) on the contrary in cropyears characterized unfavorable weather conditions (the main factor was the inappropriate amount of precipitation) the maximal yield value was around 4000 kg ha^{-1} (the yield was 3848 kg ha^{-1} in 2003) reached just the half of the values of good cropyears. We found significant differences between the natural nutrient utilization efficiency, the utilization of genetic yield ability (maximum yield in optimum fertilizer treatment), the utilization of fertilizers (yield-surplus/1 kg NPK) and the agroecologicaly optimal fertilizer demand of genotype (Nopt + PK) of the examined varieties, but these parameters were significantly modified by the effects of a given crop year. On the results of complex evaluation of examined parameters the GK Holló, Boszanova, Fatima 2, Ukrainka, GK Kapos, GK Attila, GK Kalász, Sixtus, GK Békés and the GK Csillag varieties could be characterized with excellent yield efficiency and fertilizer response on the average of several years.

5.3. Owing to fertilization the surplus yield was 3200 kg ha^{-1} on the basis of average yields of 31 examined wheat varieties and crop years on chernozem soil in the Hajdúság region. The yield increasing effects of fertilization was modified by the crop year effect and the genotypes. In the case of favorable ecological (crop year) circumstances the effects of genetically determined differences among varieties were more explicit. The difference in fertilization yield surplus varied 380-1650 kg ha^{-1} in the crop year characterized by unfavorable weather conditions (2003). In contrast the favorable weather resulted greater fertilization surplus yield (3200-5100 kg ha^{-1}). The fertilizer-specific yield surplus varied between 4,52 and 29,25 kg/l kg NPK.

5.4. Our experimental results proved that in the interest of expert and variety-specific fertilization practice we have to take into consideration of the fertilizer response of each genotype. We classified into four different groups the examined varieties based on their fertilizer response:

- *Varieties characterized by moderate natural nutrient utilization and weak fertilizer response:* GK Öthalom, Mv Verbunkos, Mv Emese, Mv Palotás, Saturnus, Mv Suba, Mv Mazurka, GK Talon, Mv Walzer and Mv Csárdás
- *Varieties characterized by bad natural nutrient utilization and excellent fertilizer re sponse:* Fatima 2, Mv Süveges and KG Széphalom
- *Varieties characterized by good natural nutrient utilization and weak fertilizer response:* Lupus, GK Petur, GK Attila, Mv Magvas and GK Nap
- *Varieties characterized by good natural nutrient utilization and excellent fertilizer response:* Boszanova, GK Holló, Ukrainka, GK Kapos, Mv Ködmön, Kunhalom, Novalis, Sixtus, GK Memento, GK Kalász, GK Békés, Biotop and GK Csillag

5.5. The Kang's yield stability analysis proved to be efficient evaluation method for the analysis of the different genotypes responses in relation with the changing environmental conditions. The most stable but lowest yield (2500-4000 kg ha^{-1}) was obtained in the control treatment. The greatest increase of the yield was observed in the N_{60}+PK treatments under improving environmental conditions (7000-8000 kg ha^{-1}), while the N_{90}+PK treatment resulted the largest yield increment (5500 kg ha^{-1}) in the case of less favorable environmental conditions. Among of the examined varieties the Lupus proved to be the most stable. The variety of GK Kapos can be considered as the most instable and sensitive.

5.6. On the basis of the results of regression analysis, in the average of examined varieties, the agroecologicaly optimal nutrient demand of examined genotypes varied between the following values 84-118 kg ha^{-1} of N, 64-86 kg ha^{-1} of P_2O_5 and 75-100 kg ha^{-1} in the case of K_2O. Under weaker environmental conditions the values of the agroecologicaly optimal NPK doses were shifted toward the higher levels on the contrary, due to the improving environmental conditions the optimal NPK demand was at lower level.

5.7. Our results proved that the variety, the crop year and the fertilization together has modified the examined quality parameters. The variety has the greatest effect on the wet gluten contents and the valorigraph value which were modified greatly, the gluten elasticity and the Hagberg Falling Number were modified weakly by the crop year and the fertilization. In the experimental years the GK Attila, Mv Verbunkos, Saturnus, Mv Mazurka, Mv Suba, Ukrainka, GK Kalász and the Lupus varieties showed outstanding values of wet gluten content. In the case of Mv Suba, Lupus, Saturnus, Mv Emese, GK Kalász, KG Széphalom, Mv Mazurka and the GK Békés varieties we found very high values of valoriograph index (above 70) during the experimental years. Due to the higher doses of fertilizer the HFN values were increased in the most cases of varieties. The gluten elasticity increased with parallel the higher fertilizer doses (up to the $N_{120-150}$+PK levels). The values of gluten elasticity varied between 3.52 and 12.04 mm in the average of the varieties.

5.8. In the case of examined quality parameters the stability of quality were various in the different fertilization treatments in the crop year of 2003-2007. On the effects of fertilization the stability of wet gluten content and the gluten spreading values increased. The analysis of stability proved that both of the wet gluten content and the gluten spreading values were the most stabile under the N_{150}+PK treatment. We did not managed to detect any increments of the stability neither case of valoriograph index nor Hagberg Falling Number. Supposedly these parameters are influenced by other environmental and agrotechnical factors considerably. In the case of valoriograph index and the Hagberg Falling Number the maximum stability were reached under the control treatment.

6. Results for practical utilization

6.1. Results of our fertilization experiments carried out on chernozem soil in the Hajdúság region proved that the effects of fertilization on the increments of yield were modified by the effects of different genotypes and crop years. In favorable crop years – in the average of varieties – we reached around 7000 kg ha^{-1} yield values (the yield was 7389 kg ha^{-1} in 2004 and 7020 kg ha^{-1} in 2005) on the contrary in crop years characterized unfavorable weather conditions (the main factor was the inappropriate amount of precipitation) the maximal yield value was around 4000 kg ha^{-1} (the yield was 3848 kg ha^{-1} in 2003). The precipitation of the crop year has the mean effect on the yield surplus (in the average of the examined winter wheat genotypes and the crop years 940-3861 kg ha^{-1}).

6.2. On chernozem soil in the region of Hajdúság, the agoecologicaly optimal nutrient demand of examined genotypes varied between the following values 84-118 kg ha^{-1} of N, 64-86 kg ha^{-1} of P_2O_5 and 75-100 kg ha^{-1} in the case of K_2O. Under weaker environmental conditions (in 2006) the values of optimal NPK doses were shifted toward the higher levels – varied in wide range of values (N 102-153 kg ha^{-1}, P_2O_5 77-101 kg ha^{-1} and K_2O 90-120 kg ha^{-1}). Due to the improving environmental conditions (in 2004), the optimal values in the case of N, P_2O_5 and K_2O varied between 87-99, 65-74 and 77-85 kg ha^{-1} respectively.

6.3. The varieties adaptation to the favorable and unfavorable environmental conditions was different. We have to change different genotypes of winter wheat for the extensive or low-input wheat producing technology than in the case of intensive or mid-tech producing technology which demand higher cost level. Those varieties are recommended for the extensive producing technologies which are capable to reach appropriate yield from the economical aspects because of their excellent natural nutrient utilization capacity in the case of application of lower fertilizer doses due to the limited resources. On the basis of our research carried out on chernozem soil in the Hajdúság region the varieties of Lupus, GK Petur, GK Attila, Mv Magvas and the GK Nap are the suitable genotypes for the extensive wheat producing technology. In the case of intensive producing technology it may be supposed application of greater doses of fertilizer because of the higher cost level, therefore wheat varieties characterized by excellent fertilizer response and good natural fertilizer utilization capacity are suitable for this technology. On the basis of our research results the Fatima 2, Mv Süveges, KG Széphalom, Boszanova, GK Holló, Ukrainka, GK Kapos, Mv Ködmön, Kunhalom, Novalis, Sixtus, GK Memento, GK Kalász, GK Békés, Biotop, and the GK Csillag varieties are suggestible for the intensive wheat producing technology adaptated on chernozem soil in the region of Hajdúság.

6.4. The stability analysis of the fertilizer treatments proved that the most stable but lowest yield (2500-4000 kg ha^{-1}) was obtained in the control treatment during the five year long investigation period. The greatest increase of the yield was observed in the N_{60}+PK treatments under improving environmental conditions (7000-8000 kg ha^{-1}).

6.5. In accordance with marketability during the winter wheat producing there is very important to emphasize the importance of variety-specific fertilization in shaping of quality parameters. Appropriate nutrient supply by the using of variety-specific fertilization could increase the yield quality, which is significantly modified by the genotypes and the character of the actual crop year in each type of quality parameter. The increments of quality was strong in the case of wet gluten contents, but was moderate for instance of gluten elasticity, valoriograph index and the Hagberg Falling Number. The improvement of quality and the stability of quality parameters were observed in the treatments with higher fertilizer doses. Application of the appropriate fertilizer dose for a given variety make it possibly to increase the amount and stability of yield moreover there was possible to reach better and more stabile quality.

6.6. On the basis of complex analysis of the amount and quality of yield of our experiments in Hajdúság, on chernozem soil the following winter wheat varieties producing can be suggest:

- Varieties with great average yield but weaker baking quality: GK Holló, Boszanova, GK Kapos, GK Petur, GK Öthalom, Fatima 2, Novalis, GK Memento, GK Kalász, GK Békés and GK Csillag
- Varieties with weaker average yield but excellent baking quality: GK Attila, Mv Verbunkos, GK Nap, KG Széphalom, GK Talon and Biotop
- Varieties with good average yield and good baking quality: Saturnus, Mv Mazurka, Mv Suba, Lupus, Ukrainka, Mv Ködmön, Mv Süveges, Kunhalom and Mv Magvas.

Main publication in connection with dissertation

Publication with IF:

Á. BALOGH-P. PEPÓ (2006): Interactions of cropyear and variety in winter wheat management. Cereal Research Communications, 34. 1. 389-392. (IF. 1,037)

M. HORNOK-P. PEPÓ-Á. BALOGH (2006): Evaluation of quality ang quantity parameters in winter wheat production on chernozem soil. Cereal Research Communications, 34. 1. 481-484. (IF. 1,037)

Á. BALOGH-HORNOK M.-P. PEPÓ (2007): Study of physiological parameters in sustainable winter wheat (Triticum aestivum L.) production. Cereal Research Communications, 35. 2. I. 205-208. (IF: 1,190)

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