Theses of doctoral (PhD) dissertation

EFFECT OF NUTRIENT SUPPLY AND CROP YEAR ON AGRONOMIC CHARACTERISTICS AND BAKING QUALITY OF WINTER WHEAT GENOTYPES IN HAJDÚSÁG

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1. INTRODUCTION

Wheat is the cereal that has the largest production area. Wheat is produced on almost one third of the acreage of cereals. In these days, wheat, as the most important bread crop, is grown on nearly 217 million hectares. In 2011, India (13%), China (11%), Russia (11%), the USA (8%), Australia (6%) and Kazakhstan (6%) produced most of wheat yield. Hungary, in 2011, had the 30th largest acreage of wheat among countries. Countries of the European Union have 12% of the production area of wheat, from which France, Germany, Poland, Romania and the UK have the largest acreage. Importance of the role of wheat in feeding is clearly shown by the fact that while in the last few decades its production area was fluctuating only in a lower extent, in the last 50 years due to the continuously developing genetic improvements, agricultural technologies and intensive production systems, average yield increased by threefold (from 1 t ha^{-1} to 3 t ha^{-1}) in the world, production changed from 200 million tonnes to nearly 700 million tonnes, thus satisfying the increasing population of the world. In our days, in Hungary, production of wheat gives an average yield of 3-5 t ha^{-1} and a yield of 3-6 million tonnes. Cereals prevail in the crop structure of our country, acreage of wheat is already beyond the maximum potential in an optimal crop structure, and thus, its production area cannot be extended further. Consequently, in our country, a proper amount of wheat and even more its crop of an excellent quality should be produced. Climate of Hungary and characteristics of its relief is very favourable for wheat production. Here, winter wheat is produced on one fourth of the 4.5 million hectares arable land. As wheat can adapt well to the environment, winter wheat is produced on the whole territory of the country. Due to the quantity and distribution of precipitation, and good soil conditions, production results in good yields with excellent quality of crop. To develop our wheat production, for the future, as a basic condition, its yield has to be increased, while yield stability and crop quality have to be improved. The quality of wheat is determined together by a number of ecological, biological and agricultural factors, thus determination of quantity and models of quality requires a complex research, where the effect and also the interference of those factors can be analysed. New varieties of wheat got into production show significant differences not only in yield, yield stability and agronomic characteristics but also in wheat dough performance and bread quality. For quality wheat production it is essential to choose the right varieties. At the same time, it is also important, how stable those genetically determined characteristics are and how they can be realized in practice, in different ecological and agricultural conditions.

2. RESEARCH OBJECTIVES

In our research we examined nutrient uptake and fertilizer response of wheat varieties of different genotypes with different dosage of fertilizers. In the analyzed crop years we were searching for answers to how different climate and crop year conditions effect crop quality and yield, and with the results, we aimed to create a model which helps us to be able to forecast the expectable yield and crop quality right before harvesting. Among agricultural factors, nutrition played the main role, and also parameterization of how certain physiological plant parameters (SPAD, LAI, and LAD) affected yield and quality parameters. We analysed the classical quality parameters of wheat (flour protein content, wet gluten content, wet gluten extension, valorigraphic value, Hagberg's falling number), and that how they affect each other with crop year conditions, agricultural and physiological properties.

3. MATERIALS AND METHODS

3.1. Experimental site, soil of the experimental area

The small-plot experiment took place on the Látókép Experimental Station of the Institute of Crop Sciences, University of Debrecen. The experimental station is located 15 km from Debrecen to the west, along main road No.33, on loess soil in Hajdúság. Soil of the test area is calcareous chernozem soil formed on loess, with deep humus layer, and is in good condition. Physically it is loam soil category, its plasticity index according to Arany is 43, the cultivated layer has nearly neutral pH (it varies between pH 6.3 - 6.5 (KCl)). The thickness of the humus layer in the soil of the test area is of 80-90 cm, the thickness of the layer in which humus is spread evenly is of 40-50 cm, with an average of 2.8% of humus content. The lime layer, which appears in the form of plaque on soil particles, occurs in depth of 75 cm. The lime content in that layer is 10-13%. The soil of the test area has a medium Nitrogen supply, and its total nitrogen concentration is 0.12-0.15% in the upper soil layer of 0-50 cm. Phosphorus supply of the soil is medium-high, the AL-soluble P_2O_5 concentration is 133 mg kg^{-1} of, the AL-soluble K_2O content shows a good supply (240 mg kg^{-1}). The soil of the area is of category No. IV according to Várallyay's classification system, which is characterized by moderate water absorbing capacity and good water storage capacity. Useable water is 50% of water absorbing capacity. The water table depth is 3-5 m, it does not rise above 2 m even in rainy crop years.

3.2. Experimental setup and the agrotechniques applied in the experiment

The long-term experiment was started in autumn of 1983, and from 1984, after the first year's so-called blind test, it was continued as a regular experiment. The small-plot field experiment was set up in a split-spot design in four replications. The gross area of parcels was 18.0 m^2. The forecrop in the experiment was sweet corn in each year, which is a good forecrop of winter wheat. The applied fertilizer was Kemira Optima complex fertilizer (10:15:18), that was spread on the area, thus, 50% of the nitrogen and 100% of phosphorus and potassium was distributed in the autumn. For the winter wheat stands, in the spring, as head fertilizer, 50% of nitrogen was distributed in the form of ammonium nitrate (34% N). Nutrient dosages had been modified since crop years 1996-1997, previously distributed fertilizer dosages had been halved, and varied up to nowadays as shown in *Table 1*.

Table 1. **Fertilization treatments applied in the long-term experiment**

(Debrecen, chernozem soil)

Treatment	N	P_2O_5	K_2O
	kg ha^{-1}		
Control	0	0	0
N_{30}+PK	30	22.5	26.5
N_{60}+PK	60	45	53
N_{90}+PK	90	67.5	79.5
N_{120}+PK	120	90	106
N_{150}+PK	150	112.5	132.5

3.2.1. Winter wheat varieties tested in the experiment

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

3.2.2. Agrotechniques applied in the experiment

In the experiment, we tried to perform agrotechnical operations in optimal times. Soil tillage methods have been combined in a way that maintained a favourable condition of the soil, and which damaged the soil structure as less as possible. We tried to adjust the method of preparation of the soil to moisture status of it, and if possible, to replace plowing with another basic form of tillage. The autumn fertilizer was applied prior basic tillage, and the spring head fertilizer was spread in early spring to ensure proper utilization. In the long-term experiment, during plant protection treatments, for comparison purposes, the same broad-spectrum herbicides and fungicides were used each year. Plant protection treatments were applied at the beginning of the appearance of diseases, at the 2-3 nodal stage and during flowering. Pests did not appear in the stands, therefore plants were not treated against them. Crop in the stands were harvested in full maturity, in order to avoid any loss of quality. In the long-term experiment, uniform previous cropping, optimized cultivation and agricultural techniques were used. In order to have the differences between genotypes and nutrition treatments as the main factors to be analyzed, we tried to perform agro-technical operations in coordinated and at appropriate points of time.

3.3. Evaluation of the weather of the tested crop years

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 2.*). From mid-October precipitation was above average, and temperatures were favorable for development and firming of the wheat stands. 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).

Table 2. **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*

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).

3.4. The method of the measurements and the evaluation of the results

3.4.1. The physiological measurements conducted in the long-term experiment

In crop years 2011 and 2012, we performed physiological measurements in the winter wheat stands. With physiological measurements, relative chlorophyll concentration, leaf area index and leaf area duration were investigated. The relative chlorophyll concentration of wheat leaf was measured with Konica-Minolta SPAD 502 Plus portable chlorophyll meter, and the leaf area index (LAI) was measured with SunScan Canopy Analysis Systems (SS1) portable leaf area meter. The measurements were carried out in the untreated control plots and at N_{60}+PK and N_{120}+PK nutrient levels. They were performed during the growing season in different phenological stages, the dates of which are shown in *Table 3*.

Table 3. ***The date of physiological measurements conducted in the long-term experiment***
(Debrecen, 2011-2012)

Tillering	-	2012.03.29.	BBCH 22
Shoot formation	2011.04.18.	2012.04.19.	BBCH 29
2-3 nodal stage	2011.05.03.	2012.05.09.	BBCH 32
Flowering	2011.05.23.	2012.05.23.	BBCH 65
Milky maturation	2011.06.14.	2012.06.08.	BBCH 73
Wax-ripening	2011.06.20.	2012.06.19.	BBCH 80

The SPAD value of early phenological stages was measured on the youngest fully developed leaves, and then on the flag leaf. The leaf area duration (ΣLAD_{LAI}) was calculated from the LAI values, based on the data gained from earing to wax-ripening.

3.4.2. Quality measurements

The quality parameters were measured in the accredited Central Laboratory of the University of Debrecen CAAES FAFSEM. The tests were carried out according to the following standards: the wet gluten content MSz ISO 5531:1993, the wet gluten extension was tested according to MSz ISO 6369-5:1987, the valorigraphic value was tested according to MSz ISO 5530-3:1995, the Hagberg's falling number value was tested according to MSz ISO 3093:1995, the flour protein content was tested according to ICC 159:1995 standard. Quality parameters of winter wheat were tested at the control, at N_{60}+PK and at N_{120}+PK nutrient levels.

3.4.3. Evaluation methods of the experimental results

The experimental data were evaluated by programmes *Microsoft Excel 2010*, and *SPSS 17.0 for Windows*. Results were analyzed by two-way analysis of variance based on the method of Sváb (1981). Relationships between the tested parameters were analyzed with Pearson's correlation analysis, regression analysis, and Kang's stability analysis. Impact of genotype, nutrient management and crop year on yield, valorigraphic value, wet gluten content and flour protein content was determined by partitioning variance components.

4. RESULTS, MAIN STATEMENTS OF DISSERTATION

4.1. The effect of the crop year, the fertilization and genotype on the physiological properties of the winter wheat

We investigated the relative chlorophyll content (SPAD value), leaf area index and duration of different phenophases in crop year 2010/2011 and 2011/2012. We tried to find an answer to how the examined physiological properties correlate to genotype, nutrient management, and the crop year.

In 2011, from shoot formation (BBCH 29) to flowering (BBCH 65) the relative chlorophyll content values increased in every variety (*Figure 1.*). The effect of nutrient treatments and nutritional response of varieties shows that during shoot formation (BBCH 29) compared to values of the control treatment, the values of chlorophyll content of all the five tested varieties were significantly higher at the N_{120}+PK nutrient level. On this same nutrient level, the maximum SPAD values could be measured during flowering with variety GK Öthalom (BBCH 65) and at the 2-3 nodal stage with the other four varieties (BBCH 32). After flowering, at the phenophases of grain filling, there was a decrease in SPAD values. In the control treatment, variety Mv Toldi showed a 75% decrease (10.4) in the chlorophyll content at the beginning of wax-ripening (BBCH 80), while at N_{120}+PK nutrient level, during wax-ripening (BBCH 80) it showed a 59% decrease (21.9). At the beginning of wax-ripening (BBCH 80), in case of GK Öthalom variety (5,5) 86%, and Lupus variety to (4,4) 90% relative reduction in chlorophyll content was observed in the control treatment. At N_{120}+PK nutrient dose, at the beginning of the wax-ripening (BBCH 80) the rate of decrease with GK Öthalom was (4,2) 91%, and with Lupus it was (8.9) 81%. In contrast with this, Pannonikus and Genius varieties showed a significantly smaller decrease even during wax-ripening. At the beginning of wax-ripening (BBCH 80) variety Pannonikus showed a (23.5) 48% decrease, and variety Genius had a (19.7) 59% loss in its chlorophyll content. At N_{120}+PK nutrition level, the extent of the decrease during wax-ripening (BBCH 80) was (41.8) 26%, with variety Pannonikus and it was (35.6) 41% with variety Genius.

In 2012, at the control and N_{60}+PK nutrient levels, the varieties reached their maximum chlorophyll content at the 2-3 nodal stage (Lupus 45.1-51.2, Pannonikus 49.5-53.3, Genius 53.5-58.6, Mv Toldi 44.8-51.5), except variety GK Öthalom, which reached its maximum SPAD values (48.3-53.3) during flowering. At N_{120}+PK nutrition level, varieties GK Öthalom (58.2), Pannonikus (56.3) and Genius (62.2) showed the maximum values of chlorophyll content at the beginning of the milky maturation stage.

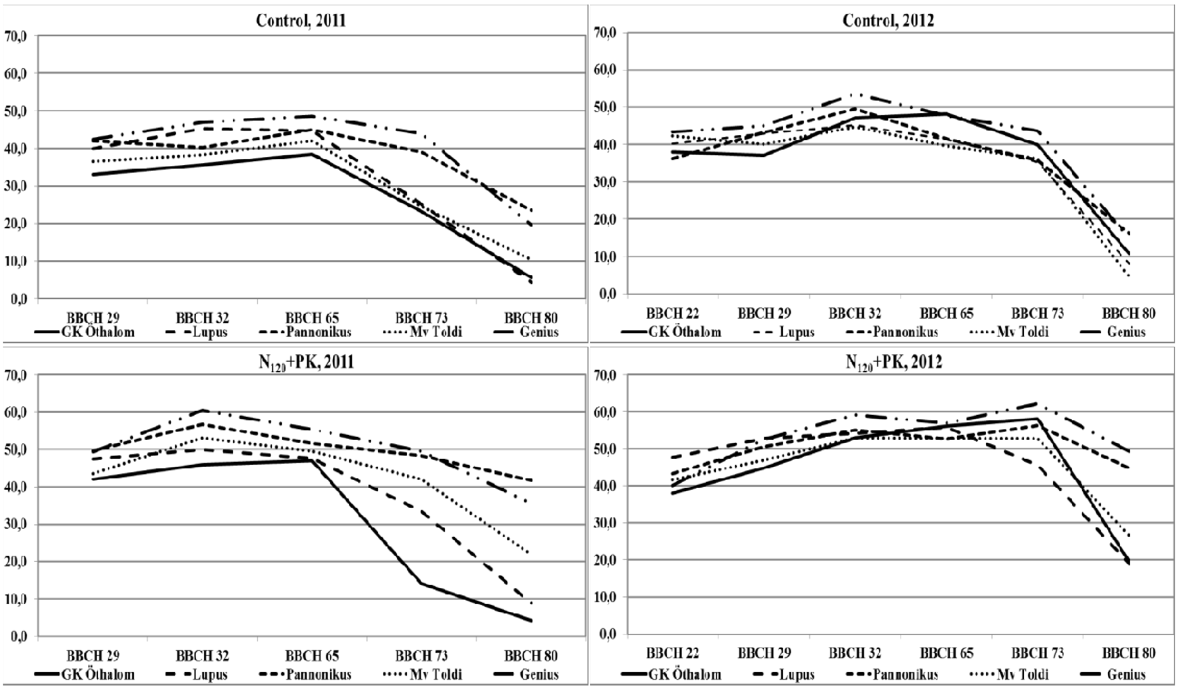

Figure 1. **Effect of the genotype and the fertilization on the relative chlorophyll content of the winter wheat varieties**

(Debrecen, 2011-2012)

Variety Lupus showed the highest chlorophyll content (55.9) during flowering, while variety Mv Toldi reached (52.9) at the 2-3 nodal stage. Decreasement in the SPAD values was significantly higher in the control plots than in case of the nutrient treatments. The extent of the decrease during wax-ripening (BBCH 80) was different with each variety. GK Öthalom lost 80%, Lupus lost 66% of its chlorophyll content. In case of Mv Toldi, 50% decrease occurred in the SPAD values. At N_{120}+PK nutrient dose, in case of varieties Pannonikus (20%) and Genius (21%) reduction in chlorophyll content was significantly lower in the grain filling stages.

As the phenological stages were progressing and nutrient dosages were increased, in case of all the five varieties, the leaf area index was increasing until flowering (*Figure 2.*).

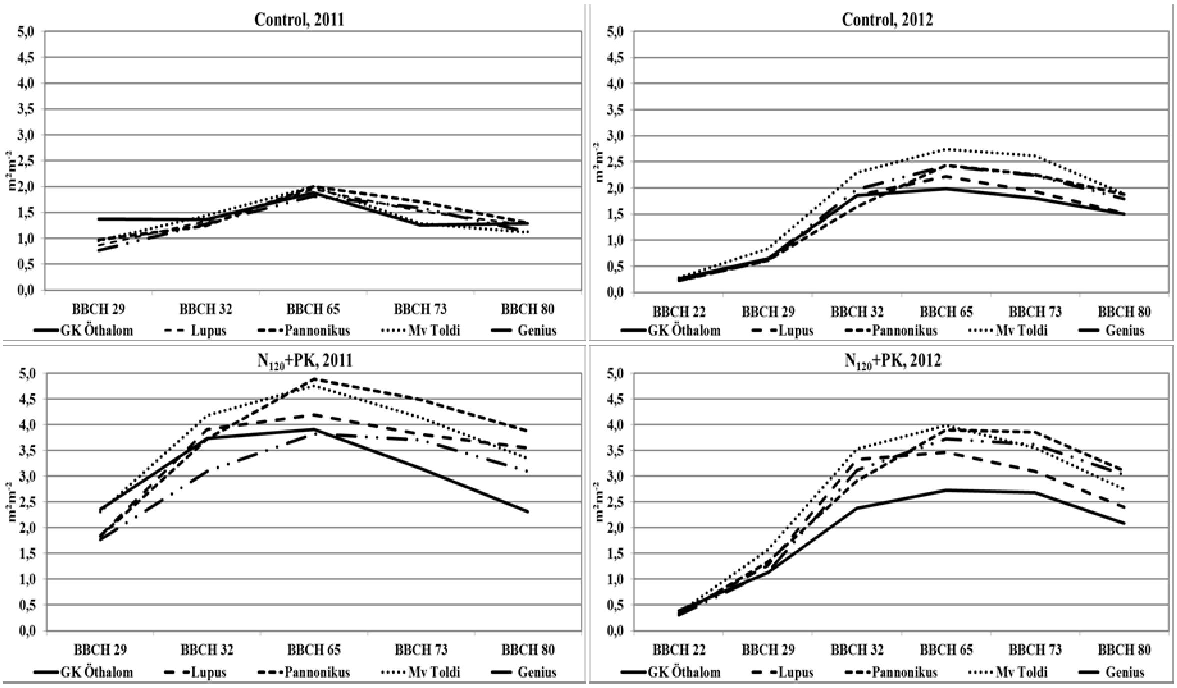

Figure 2. **Effect of the genotype and the fertilization on the leaf area index (m^2 m^{-2}) of the winter wheat varieties**

(Debrecen, 2011-2012)

Varieties produced leaf surfaces of different sizes, while GK Öthalom (1.9-3.9 m^2m^{-2}) and Genius (1.8-3.8 m^2m^{-2}) reached lower maximum values of leaf area index. Lupus reached an intermediate value (1.9-4.2 m^2m^{-2}), Pannonikus (2.0-4.9 m^2m^{-2}) and Mv Toldi (2.0 to 4.8 m^2m^{-2}) showed larger leaf area maximum. As a result of nutritional treatment at N_{120}+PK nutrient dose, varieties showed the following increase in leaf area: GK Öthalom 38%, Lupus 57%, Pannonikus 63%, Mv Toldi 52%, and Genius 53%. In the grain filling stages, leaf area of all the five winter wheat varieties decreased. The reduction in the control plots was significantly greater than with nutrient treatment at the N_{120}+PK nutrient dose, except with GK Öthalom, which had a decrease of 32% in the control treatment and a 41% decrease at N_{120}+PK nutrient level. Variety Lupus showed a decrease of 32% in the control treatment, while showed only 14% decrease with nutrient treatment. In case of variety Pannonikus the decrease was 35% in the control treatment, while it was 20% at maximum nutrient dose. In case of variety Mv Toldi, the 45% decrease in the control treatment reduced to 31% with nutrient treatment. The nutrient treatment has the most considerable impact on variety Genius, where the 39% reduction measured in the control treatment decreased to 18%. In 2012, greater increase in the leaf area values was observed in May. Varieties reached their maximum leaf area at the 2-3 nodal stage and during flowering, which was due to the rainy weather in May and June as well. After creating the maximum leaf area, it showed a slighter decrease compared to the previous year, nutrient treatment only slightly reduced the extent of the fall. In case of GK Öthalom 25-22%, Lupus 32-31%, Pannonikus 21%, Mv Toldi 30% decrease was detected. The effect of nutritional treatment was the most conspicuous on variety Genius again. The 25% reduction observed in the control stand decreased by 19% in the nutritional treatment.

Analyzes of leaf area duration (LAD) values reveals that the leaf area duration is significantly affected by not only the genotype and the nutrient supply, but also by the crop year (*Table 4.*). In 2011, in case of winter wheat varieties the leaf area duration was significantly higher, while in the drier crop year 2012, lower values were determined. The drier crop year has a particularly adverse effect on GK Öthalom and Lupus varieties, while Pannonikus, Mv Toldi, and Genius varieties had better leaf area duration values in both years.

Table 4. **Effect of genotype and fertilization on leaf area duration (m^2 m^{-2} day) of winter wheat varieties**

(Debrecen, 2011-2012)

	2011			**2012**		
	Ø	***N_{60}+PK***	***N_{120}+PK***	***Ø***	***N_{60}+PK***	***N_{120}+PK***
GK Öthalom	42.2	65.8	94.0	51.8	72.7	74.3
Lupus	46.5	77.8	110.2	55.6	85.8	88.2
Pannonikus	49.9	90.1	128.3	64.4	106.3	107.3
Mv Toldi	43.4	83.8	120.3	72.3	93.3	101.2
Genius	45.6	71.1	103.2	63.6	98.5	101.9
$LSD_{5\%\ Genotype}$	**15.8**			**12.1**		
$LSD_{5\%\ Fertilization}$	**19.0**			**14.5**		
$LSD_{5\%\ Interaction}$	**42.5**			**32.5**		

Effect of the nutrient treatments on physiological properties were analyzed using Pearson's correlation analysis (*Table 5.*). Between nutrient supply and the SPAD values, it was a strong positive significant relationship from shoot formation till flowering (BBCH 29-65). In the phenophases of grain filling (BBCH 73-80) correlation was only a moderately strong significant (0.358-0.431). The leaf area index values had significant strong correlation (0.654-0.646) with nutrient supply from shoot formation till the 2-3 nodal stage (BBCH 29-32), they were in strong correlation (0.734 to 0.740) with LAI values during flowering (BBCH 65) and the stage of milky maturation.

Table 5. **The result of the Pearson's correlation analysis between the fertilization and the physiological properties of winter wheat**

(Debrecen, 2011-2012)

	SPAD					LAI					LAD
	BBCH 29	**BBCH 32**	**BBCH 65**	**BBCH 73**	**BBCH 80**	**BBCH 29**	**BBCH 32**	**BBCH 65**	**BBCH 73**	**BBCH 80**	
Fertilization	0.572**	0.563**	0.627**	0.358**	0.431**	0.654**	0.646**	0.734**	0.740**	0.688**	0.778**

*** significant at P<0.01 level, * significant at P<0.05 level*

LAI values measured during grain filling were in strong significant correlation (0.688-0,740) with the nutrient management. The leaf area duration had a strong correlation with the nutrient supply (0.778).

4.2. The effect of the crop year, the fertilization and the genotype on the yield of the winter wheat

During our research our aim was to investigate the effect of genotype, nutrient supply and crop year separately and together.

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. 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 (4719 kg ha^{-1}). 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).

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 6.*), 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 6. **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 3.*) 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.

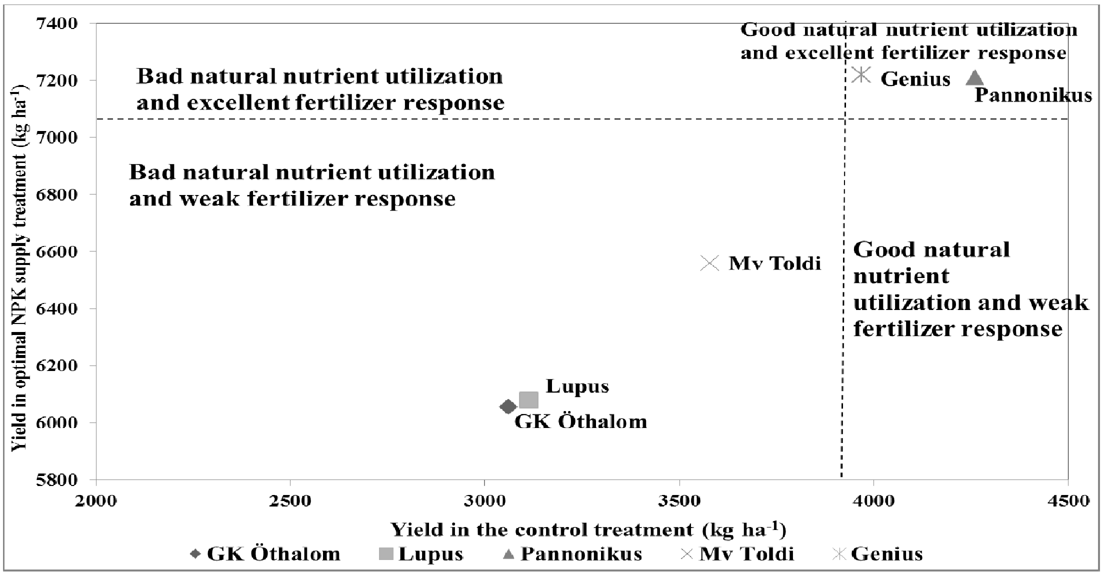

Figure 3. **Types of nutrient response of the examined winter wheat genotypes in the average of the three crop years**

(Debrecen, 2010-2012)

Yield stability of the varieties was analyzed with Kang's stability analysis. It can be observed (*Figure 4.*) that varieties that can be considered as stable, i.e. GK Öthalom (b = 0.607), Lupus (b = 0.0197) and Mv Toldi (b = 0.5997), although which reached a lower yield, they produced similar yields sometimes effected even by extreme ecological conditions.

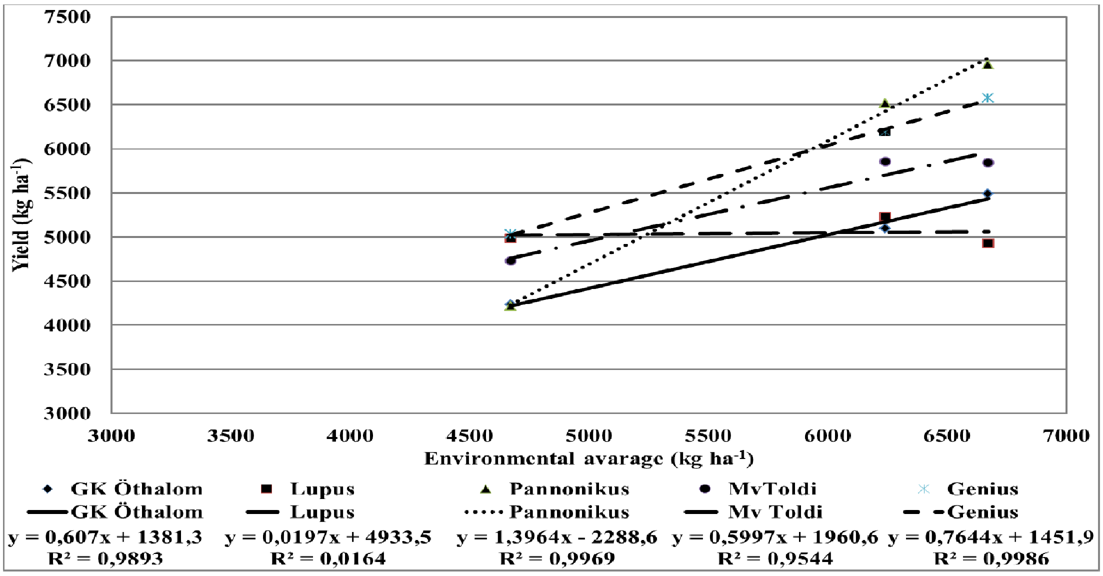

Figure 4. **Yield stability of winter wheat varieties in the tested crop years**

(Debrecen 2010-2012)

In contrast, variety Genius showed moderately stable result (b = 0.7644), variety Pannonikus proved to be the least stable (b = 1.3964), from which it can be concluded that in the less favorable crop years it could only achieve only lower yields, but in with this variety, in more favorable ecological conditions, higher yield results could be obtained.

Based on the results of stability analysis of nutrient treatments (*Figure 5.*), it can be stated that stability of the control and of N_{30-60}+PK nutrient treatment proved to be the best, but at these nutrient levels relatively low yields were obtained. Nutrient dose N_{90}+PK was less stable (b = 0.9722), but varieties were able to achieve significantly higher yields with this nutrient dose.

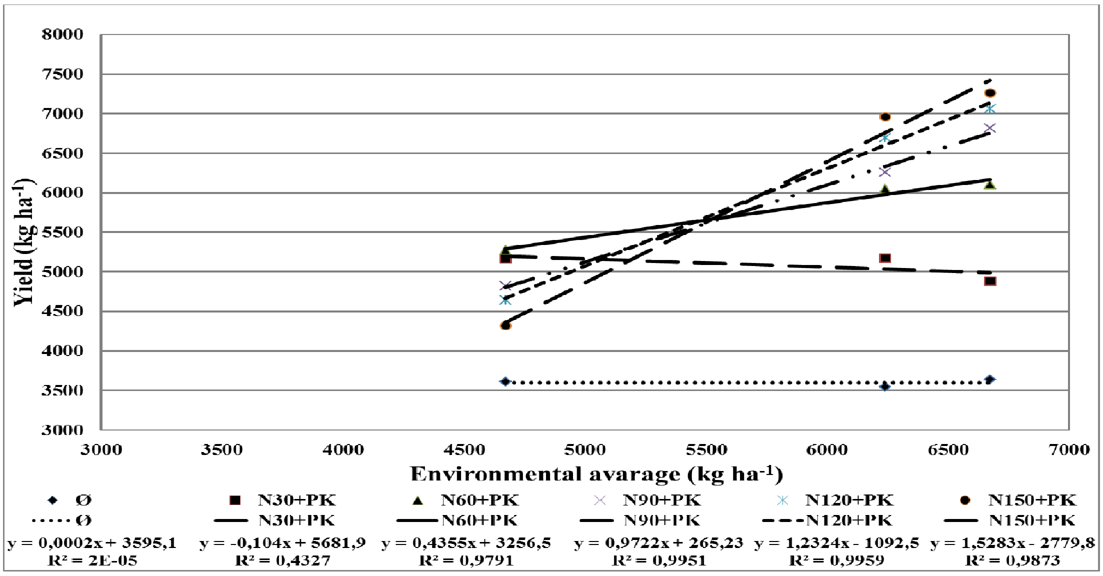

Figure 5. **Yield stability of winter wheat varieties in different nutrient treatments**

(Debrecen, 2010-2012)

The $N_{120-150}$+PK dosages showed a significantly lower stability, yield was varying depending on these nutrient levels, but the highest maximum yields were realized on these levels. With analyzing the data of the three years together, it can be concluded that realization of the genetically determined maximum fertility of the investigated five wheat varieties was strongly affected by the three different crop years.

Among the three crop years, effect of average crop year 2011 the most favorable, drought and warm crop year 2012, although to a lesser extent, but had negative impact on the yields of winter wheat, while the most intense and most adverse influence the large amounts of rain had on the stands in 2010. The ecological impacts affecting the wheat crop can be mitigated, because winter wheat reacts positively to fertilizers, thus, providing the appropriate nutrition level, negative effects can be reduced to different extents. The extent to which we can reduce those negative ecological effects depends on nutritional response of varieties, and that to what extent those ecological factors have influence on varieties.

4.3. The effect of the crop year, the fertilization and genotype on the quality of the winter wheat

In our study, we wanted to find the answer to that how intensely the environmental factors influence the quality parameters and that whether the negative effects can be reduced or eliminated with nutrient supply adjusted to the crop year. Evaluating the collectively analyzed quality parameters it can be concluded that base of differences between winter wheat varieties were characterized by the genotype. The genotype basically determined limits of maximum quality and created the realized quality of the variety with its capability to adapt to agricultural techniques and environmental effects.

In crop year 2010 high valorigraphic values were obtained with the examined winter wheat varieties. In the control treatment valorigraphic values varied between 29.2 (Pannonikus) and 53.2 (Mv Toldi). As an effect of nutrient treatments, valorigraphic values of the varieties increased significantly. At N_{120}+PK nutrient level, values ranged between 56.8 (Pannonikus) and 71.8 (Mv Toldi). Based on its valorigraphic value (71.8), variety Mv Toldi had an improved quality (A), and also the other examined varieties showed substantial improvement in quality, with milling quality B_1. In the control plots in 2011, valorigraphic values varied between 48.3 (GK Öthalom) and 60.3 (Genius). Milling quality of varieties varied between B1-B_2. The highest valorigraphic values were gained with varieties Mv Toldi (66.2) and Lupus (67.1), at N_{120}+PK nutrient level. In crop year 2012, valorigraphic values of the control treatment ranged between 44.5 (Pannonikus) and 55.0 (Mv Toldi). Varieties had B_2 milling quality or a quality close to that, except variety Mv Toldi, which has milling quality B_1, even in the control treatment. In case of nutrient dose of N_{120}+PK, valorigraphic values varied between 69.7 (Lupus) and 54.4 (Pannonikus). The varieties achieved B_1-B_2 milling quality. Variety Lupus had the best valorigraphic value (69.7), and similarly high valorigraphic value was reached by varieties Genius (63.9) and Mv Toldi (61.2), at nutrient level of N_{120}+PK.

In 2010, flour protein content proved to be favorable. In the average of the varieties, values between 11.1% and 15.9% were obtained. In the control plots Mv Toldi (12.4%) reached the highest protein content, varieties Pannonikus and Genius reached a flour protein content of 11.6%. The best results were achieved at the N_{120}+PK nutrient dose, by varieties Mv Toldi (17.0%), Pannonikus (16.5%) and Genius (16.8%). In 2011, flour protein content of the varieties was below the maximum values experienced in previous year, they varied between 12.0% to 13.8%. In the control treatments, Mv Toldi (12.9%), Lupus (12.8%), and Pannonikus (12.4%) had the highest flour protein content. At nutrient level of N_{120}+PK, Mv Toldi (15.4%), Genius (14.1%), Pannonikus and Lupus (13.9%) varieties showed high protein content. In 2012, values ranged from 11.6% to 15.0% in the average of the varieties. In the control treatment, difference between the flour protein content of varieties was not significant, we measured values between 12.3% (Mv Toldi) and 11.1% (Pannonikus). At N_{120}+PK nutrient dose, Mv Toldi (16.2%), Lupus (15.1%), Genius (14.8%), Pannonikus (14.7%), and GK Öthalom (14, 4%) varieties had high flour protein content.

In crop year 2010, wet gluten content of winter wheat varieties was good, and in the control plots the wet gluten content varied between 16.2% (GK Öthalom) and 28.0% (Mv Toldi). The average wet gluten content of varieties was 24.1%. At nutrient level of N_{120}+PK values ranged between 31.9% (GK Öthalom) and 40.0% (Mv Toldi). The highest wet gluten contents were achieved by varieties Mv Toldi (28.0% - 40.0%), Genius (26.2% -39.7%) and Pannonikus (26.2% -39.2%). In crop year 2011, wet gluten content in the untreated control plots, was relatively higher than in the previous crop year, the values were between 22.6% (GK Öthalom) and 30.0% (Mv Toldi). Variety Mv Toldi had the highest wet gluten content (36.0%) even at nutrient level of N_{120}+PK. Varieties Lupus (32.8%); Genius (32.5%) and Pannonikus (32.2%) reached relatively high wet gluten content. In the average of the varieties, due to fertilizer treatments, wet gluten content ranged from 27.2% to 32.0%. In crop year 2012, in the control plots, the lowest wet gluten content was measured, the values ranged from 18.5% (GK Öthalom) to 25.0% (Mv Toldi). At N_{120}+PK nutrient dose, values varied between 32.6% (GK Öthalom) and 39.8% (Mv Toldi). Wet gluten content of the tested varieties ranged between an average of 20.6 and 35.6%.

In crop year 2010 wet gluten extension of the varieties varied in a wide range. In the control treatment, variety Pannonikus (6.0 mm) had the highest wet gluten extension. At the N_{120} + PK nutrient dose the wet gluten extension of the variety GK Öthalom was 4.0 mm, while varieties Genius (5.9 mm), the Mv Toldi (5.6 mm) and Lupus (5.4 mm) showed a medium wet gluten extension. Varieties showed an average of 2.8 to 5.5 mm of wet gluten extension, which indicated an improving or good milling quality. In crop year 2011, wet gluten extension ranged in a narrower interval, they varied between 2.5 to 3.7 mm in the average of varieties. Values gained from the control plots ranged from 1.9 to 2.9 mm. This value of the varieties was the highest on N_{120}+PK nutrient level. Mv Toldi (4.5 mm), Pannonikus (3.9 mm) and Genius (3.8 mm) had the highest values, but these also varied in an optimal range. In 2012, values were significantly lower compared to the previous two crop years, in average of the varieties values ranged from 1.6 to 3.1 mm. In the control plots Mv Toldi showed 2.5 mm of wet gluten extension, and value of the other four varieties ranged from 1.1 to 1.6 mm. At N_{120}+PK nutrient dose, difference between varieties was not significant, wet gluten extension ranged from 2.5 to 3.3 mm.

Falling numbers in crop year 2010, despite the fact that it was extremely humid, ranged from 304.0 to 331.6 seconds in the average of the varieties, which referred to an appropriate, but slightly low enzyme activity. In this respect, differences between genotypes were considerable, while nutrient treatments had significantly not affected this quality parameter. In crop year 2011, in the average of the varieties, falling number ranged from 314.3 to 399.6 sec. These values were similar to the ones we gained from the previous crop year. Varieties Mv Toldi (357.5 to 370.0 sec) and the Genius (340.8 to 361.3 sec) reached the highest falling number, these varieties proved to be poorer in enzymes. In 2012, even despite the rainy summer season, falling number values were high. In the average of the varieties, falling number ranged from 346.0 to 383.2 seconds.

Effect of the crop year has a strong influence on the maximum value developed by genotype and fertilizer treatments. Crop year 2010 proved to be extremely humid, but the large amount of rainfall helped nutrient utilization and translocation processes, too. As a result, although in the control treatment they had lower values of quality parameters, but at higher nutrient levels, varieties had more favorable quality characteristics. Crop year 2011 was average from wheat production point of view, but the dry period in late spring and early summer was not conducive to generative processes, quality characteristics were worse than it was shown by the values gained in 2010. Although year 2012 was drier crop year, rainfall in May and June promoted grain filling processes, varieties achieved a weaker quality than in 2010, but a stronger one than in 2011.

Relationship between nutrition treatment and the examined quality indicators was analyzed by Pearson's correlation analysis (*Table 7.*).

Table 7. **The result of the Pearson's correlation analysis between the fertilization and the quality parameters of winter wheat**

(Debrecen, 2010-2012)

	Valorigraphic values	**Wet gluten content (%)**	**Wet gluten extension (mm)**	**Hagberg's falling number (sec)**	**Flour protein content (%)**
Fertilization	0.639**	0.735**	0.465**	0.129	0.684**

*** significant at P<0.01 level, * significant at P<0.05 level*

Valorigraphic values were strongly affected by nutrient supply, i.e. a close, significant correlation (0.639) was found. The nutritional management significantly influenced the wet gluten content, i.e. a strong positive significant correlation (0.735) was found. The nutrient supply modified the wet gluten extension, a moderately strong significant (0.465) correlation was found. The nutrient management had major impact in modifying the level of protein content, a strong positive correlation (0.684) was detected.

4.4. Evaluation of the relationship between physiological properties and yield of different winter wheat varieties

During our research, our aim was also to reveal the relationship between physiological properties, yields qualitative indicators.

Based on the analysis of relationships between physiological properties and yield it can be concluded in the average of the two crop years and the varieties (*Figure 6.*), that there was a strong significant correlation (0.678 to 0.460) between yield and chlorophyll content, and it is at around the same level in each of the five phenophases from shoot formation (BBCH 29) to the beginning of wax-ripening (BBCH 80). Correlation between yield and leaf area index values was strong significant. It was particularly strong during flowering (0.768 to 0.715) and grain filling stages (BBCH65-80). According to the strength of the correlation, for higher yields it is important to produce a greater leaf area and also to keep it in the ripening phenophases. Based on the regression analysis, it can be stated that showed that determination coefficients of estimators revealed medium correlations. Moderately strong correlation (r^2=0.329 to 0.460) between the SPAD value and yield was measured from shoot formation to flowering and also during grain filling stages. Correlation was moderate between the leaf area index values and yield during shoot formation and at the 2-3 nodal stage (BBCH 29-32), and it was strong from flowering to grain filling phases (BBCH 65-80) (r^2 = 0.524-0.589).

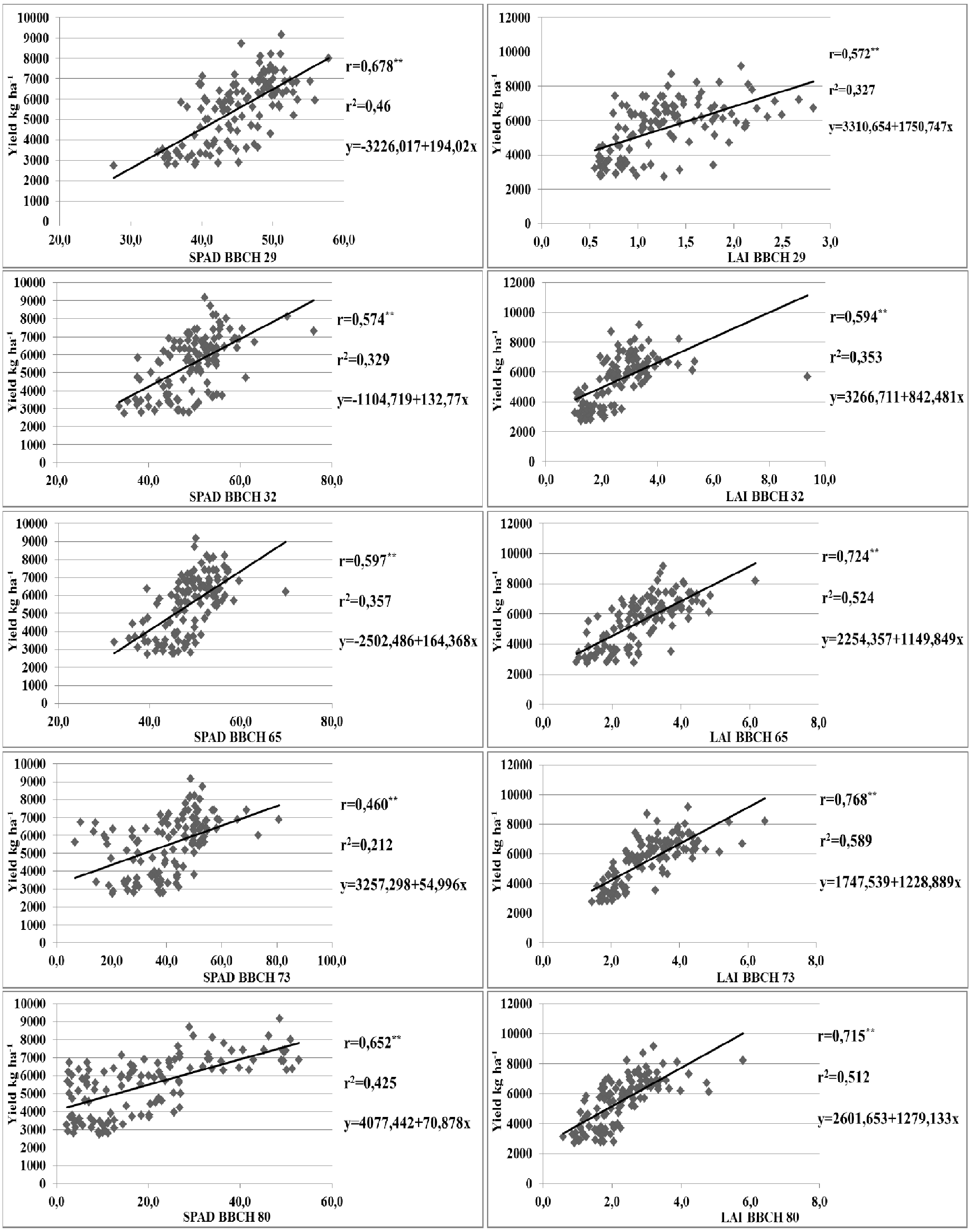

Figure 6. **Correlation and equation between yield, SPAD values and leaf area index as an average of winter wheat varieties**

(Debrecen, 2011-2012)

A very strong and significant relationship was found between the leaf area duration and the yield results in case of all the five varieties in both crop years (*Table 8.*). The data gained from the experiment also corroborated the fact that for higher yields, long-term preservation of appropriate leaf surface is really important, as well as the adequate production of the organic substances that plays role in the formation of crop and are necessary for grain filling, in generative development.

Table 8. **Correlation and equation between the yield and leaf area duration ($m^2 m^{-2}$ day)**

(Debrecen, 2011-2012)

Crop year	Variety	r	r^2	Equation
2011	GK Öthalom	0.876**	0.767	y=57.270x+1232.568
	Lupus	0.920**	0.847	y=38.133x+1644.637
	Pannonikus	0.838**	0.703	y=34.841x+3556.651
	Mv Toldi	0.909**	0.826	y=43.280x+1887.260
	Genius	0.877**	0.769	y=56.676x+2002.432
2012	GK Öthalom	0.848**	0.719	y=-86.152x+925.532
	Lupus	0.872**	0.761	y=67.247x-251.922
	Pannonikus	0.793**	0.628	y=56.338x+1027.289
	Mv Toldi	0.775**	0.601	y=64.181x-281.353
	Genius	0.837**	0.701	y=66.919x-96.788

*** significant at P<0.01 level, * significant at P<0.05 level*

Our results suggest that the genotype and the nutrient supply had significant influence on values of the studied physiological properties, while crop year considerably modified the analyzed parameters. The test results have shown that the chlorophyll content and the volume of leaf area can directly influence, alter yield. Those varieties are capable of forming higher leaf area and have higher chlorophyll content, can produce higher yield, even in different crop years. The varieties that showed a lower chlorophyll content decrease in the grain filling phenophases, and had a larger leaf surface area and leaf area duration, in the grain filling stages from flowering had a significantly higher chlorophyll content, as well as leaf area and leaf area duration, thus, produced higher yield both with the control and at the higher nutrient levels. Based on our results it can be concluded that by analyzing the chlorophyll content and the leaf area values together (especially from flowering till the early stage of grain filling), from tendency of the values we could be able to forecast the expected yield.

4.5. Evaluation of the relationship between physiological properties and quality parameters of different winter wheat varieties

Examining the correlations between the three quality parameters and physiological properties in the average of the two years and the varieties (*Figure 7.*) it can be observed that between the valorigraphic values and the SPAD values had moderately strong significant correlation (0.357 to 0.446) only from shoot formation (BBCH 29) to flowering (BBCH 65). Correlation between leaf area index values and valorigraphic values was moderately strong (0.362 to 0.444) on each date of measurement.

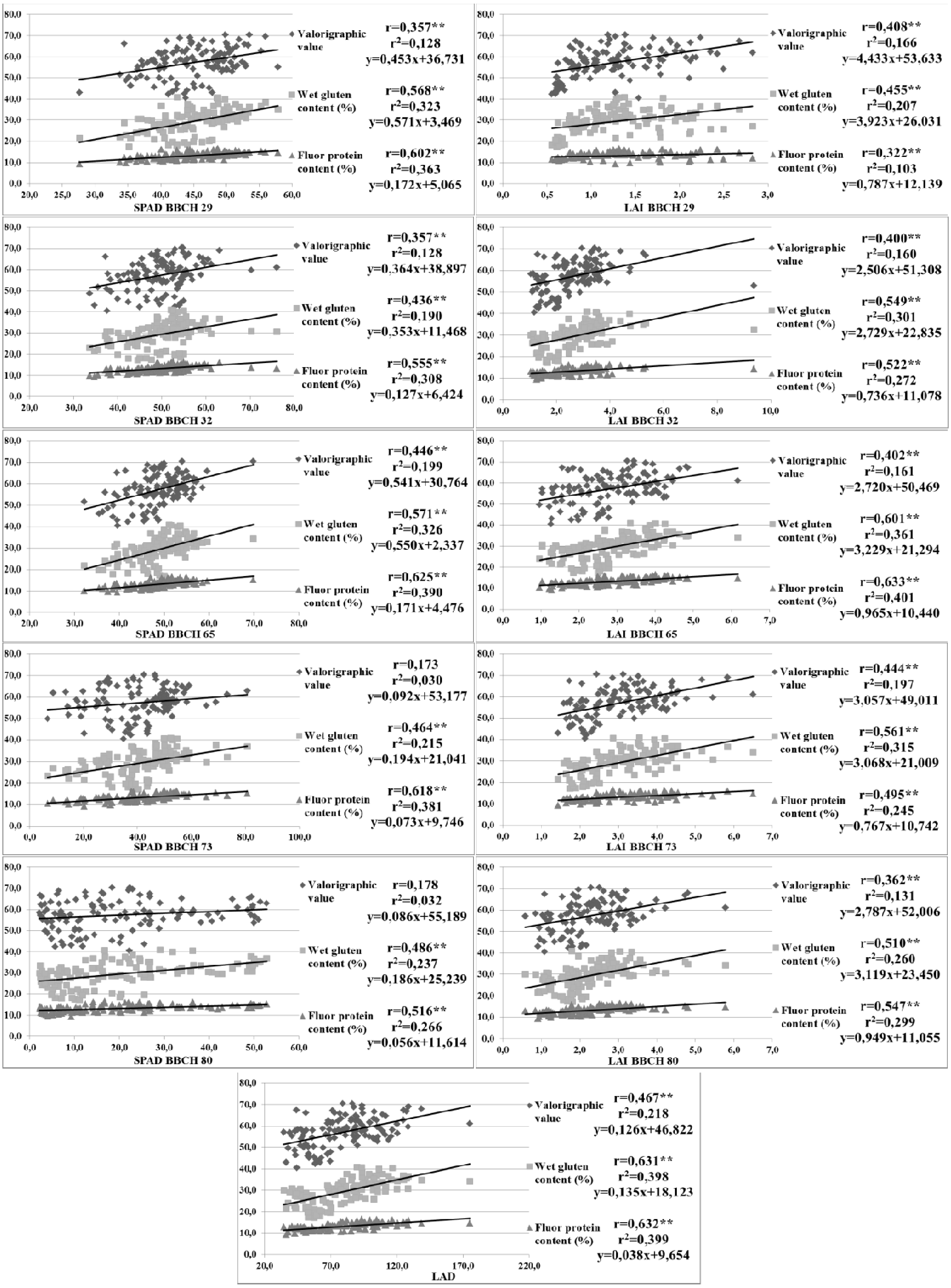

Figure 7. **Correlation and equation between the quality parameters, SPAD values, leaf area index and leaf area duration as an average of winter wheat varieties**

(Debrecen, 2011-2012)

The valorigraphic value showed a moderately strong correlation with (0.467) leaf area duration. The coefficient of determination was low, the trend lines were in weak fit. The wet gluten content showed moderately strong correlations with the SPAD values, the leaf area index values and the leaf area duration. The trend lines were in weak and middle fit. The protein content showed a strong significant correlation with the SPAD values. With the leaf area index values it had a moderately strong (0.322) correlation at the shoot formation (BBCH 29), and had a strong significant correlation on other measurement dates. The trend lines were in medium fit. It had strong significant correlation also with the leaf area duration. Differences caused by genotype were found in the tested parameters. However, several moderate and strong correlations were identified between quality parameters and physiological properties. The results showed that the chlorophyll content and the leaf area, and also the extent of their decrease in the generative phases have an impact on the quality parameters. Among the values of quality parameters, the valorigraphic value (which is a complex indicator) showed a weaker correlation with physiological properties. Thus, the valorigraphic value can be estimated by physiological properties to a lesser extent. The wet gluten content and protein content of flour is very strongly correlated with chlorophyll content and leaf area index. The relationship between the studied parameters was the most powerful during flowering, so it makes easier to predict if they are analyzed in this phenophase. Results of physiological parameters measured at the end of the vegetative stage and during grain filling periods showed a strong significant correlation between the flour protein and wet gluten content values. This shows that, collectively analyzing the data measured in different phenophases, we can recognize the extent of the assimilation capacity, which is a major determinant in terms of nutritional values of the grain produced during ripening. The wet gluten content had a moderately strong correlation with the chlorophyll content and leaf area index values, which comes from the fact that this quality parameter includes a number of other substances besides protein fractions, which can only slightly be influenced by physiological properties. The strongest correlation was found with the flour protein content, especially in case of SPAD values, which suggests that the protein content, which is a major component of the crop of wheat, is strongly determined by assimilation parameters. By examining the SPAD and leaf area values, the flour protein content can most safely be predicted and by, even in spite of different crop year effects.

4.6. Complex evaluation of the effect of the crop year, the fertilization and the genotype on the yield and the quality of the winter wheat

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, the valorigraphic value, the wet gluten content and flour protein content values. 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 8.*). 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}).

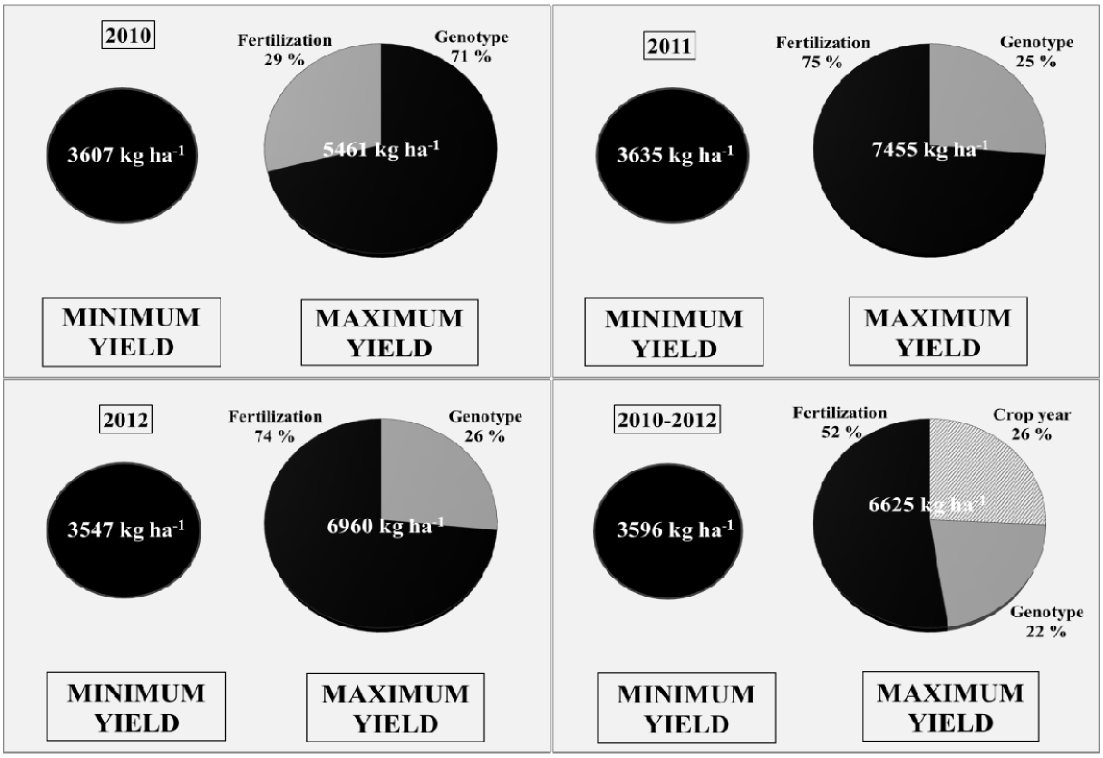

Figure 8. **The significance of the studied factors in determining yield of the winter wheat** *(Debrecen, 2010-2012)*

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.

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.

Analyzing the valorigraphic values (*Figure 9.*), in 2010, compared to the control treatment (42.9), the varieties reached 19.4 higher valorigraphic values at N_{120}+PK nutrient level (62.3). The variety caused 29%, the nutrient treatment caused 71% of the increase. The fertilizer solubilized in the wet year, has significantly more influence valorigraphic values. In 2011, the valorigraphic value was 54.6, in the average of the varieties, which increased by 7.5 with a nutrient treatments (62.2). To this increase, the genotype contributed in 37%, and 63% of it was caused by the nutrient supply. The favorable effect of crop year helped the differences between genotypes to become more observable, but the nutrient supply played an important role also in this crop year. The increase was significantly lower compared to the other two crop year. In 2012, compared to the control (47.6), a 14.3 increase in the valorigraphic values was gained due to nutrient supply (61.9). In 2012, the genotype contributed to the increase of the valorigraphic value only in 8%, while the nutrient supply caused 92% of the increase. In spite of the extreme crop year, the proper nutrient supply has considerably increased the valorigraphic values.

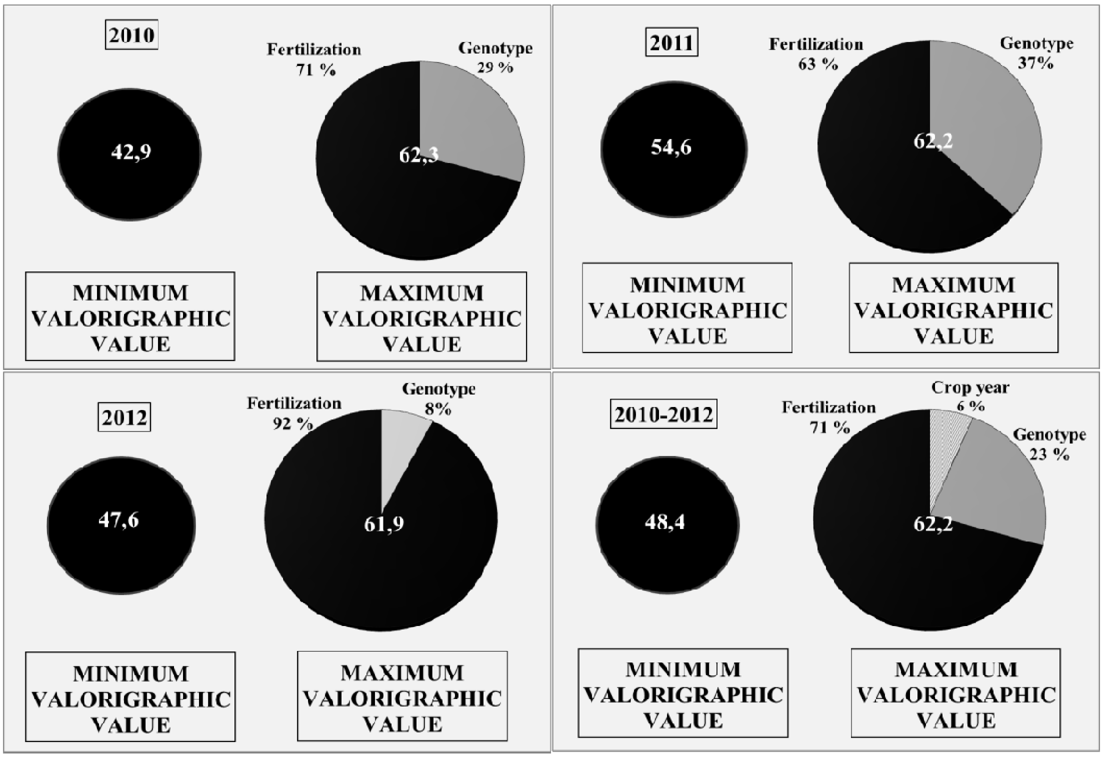

Figure 9. **The significance of the studied factors in determining the valorigraphic values of the winter wheat**

(Debrecen, 2010-2012)

While the three-year average of valorigraphic values of varieties was 48.4 on the control plots, the fertilizer treatment increased this value to 62.2, which equals to 13.8 increase. The increase was due to the crop year in only 6%, to the variety in 23%, while in 71% to the nutrient supply. In all three years, the nutrient supply played the major role, in reaching the maximum valorigraphic values, the variety had 8-37% contribution. The genotype has the highest percentage of contribution in the average crop year. In the extreme crop year it played a minimal role, contributed only in 8%.

In 2010, in the average of the control treatments the wet gluten content was 24.1%, the maximum gluten content values reached 37.8%, which was 13.7% higher than the average of the control treatment (*Figure 10.*). The increase in gluten content was due to the genotype in 38%, the nutrient supply contributed to the increase in the wet gluten content in 62%. In 2010, due to large amount of rainfall, most of the distributed fertilizer was solubilized, thus could be utilized by the varieties that has good genetic base. In 2011, average wet gluten content of the varieties was 27.2% in the control treatment, their maximum average wet gluten content at the

N_{120}+PK treatment was 32.0%, which is only a 4.7% increase. The increase in wet gluten content was due to the genotype in 54% and to the nutrient treatment in 46%. In the average crop year, when most of the environmental conditions were optimal for the winter wheat, the biological base had a more significant influence on achieving higher gluten content. In 2012, the average wet gluten content of the control plots was 20.6%, the average of wet gluten contents measured at N_{120}+PK nutrient level was 35.6%, which corresponds to a 14.9% increase in wet gluten content that was the largest among the crop years that were studied. The increment of the wet gluten content that was reached was due to the genotype in only 22%, while the nutrient supply contributed to it by 78%. In 2012, periods of extreme weather conditions followed each other (hot dry spring, rainy early summer), it was essential for the adaptation of varieties to extreme environmental conditions to ensure the proper fertilizer dosages, so that the varieties could reach higher gluten content.

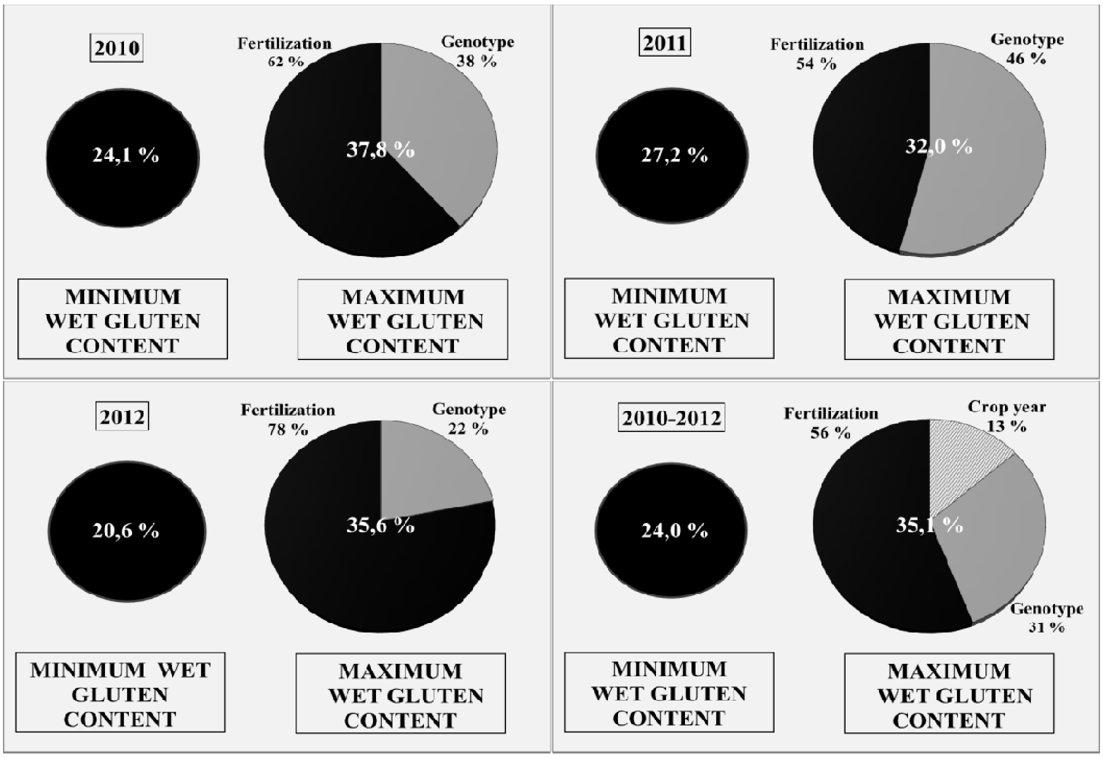

Figure 10. **The significance of the studied factors in determining the wet gluten content of the winter wheat**

(Debrecen, 2010-2012)

Studying the data of the three years together, it can be concluded that the varieties produced 24.0% wet gluten content in the control treatments, their average maximum gluten content was 35.1%, this was a 11.1% increase. Increase in wet gluten content values was caused by the genotype in 31%, and by the nutrient supply in 56%, the crop year contributed to it in only 13%. Analyzing the data of those three years together and also separately, it can be concluded that the different crop year effects only slightly modified the potential maximum gluten content. Also the genetic basis of varieties significantly determined the potential maximum wet gluten content of the variety, but the nutrient supply contributes the most to reach higher values, particularly in cases when environmental conditions significantly deviated from the optimum.

In 2010, in the control treatment, the varietal average of flour protein content was 11.1%, at the N_{120}+PK nutrient level the flour protein content increased by 4.9%, which equaled to a 15.9% average flour protein content (*Figure 11.*). The increase was the result of the genotype in 43%, and of the nutrient supply in 57%. The greater role of the nutrient supply was due to the more effective digestion, and to its compensating effect. In 2011, in average of the control treatments the flour protein content was 12.0%, which increased to 13.8% at N_{120}+PK nutrient level, i.e. 1.8% increase in protein content was achieved in the average of varieties. The variety contributed with 54%, the nutrient supply played a role in 46% in the increase. The greater role of genotypes is due to the optimal environmental conditions, resulting in better enforcement of the genetic potential of varieties. Nutrient supply had also significantly affected the achievement of higher maximum values.

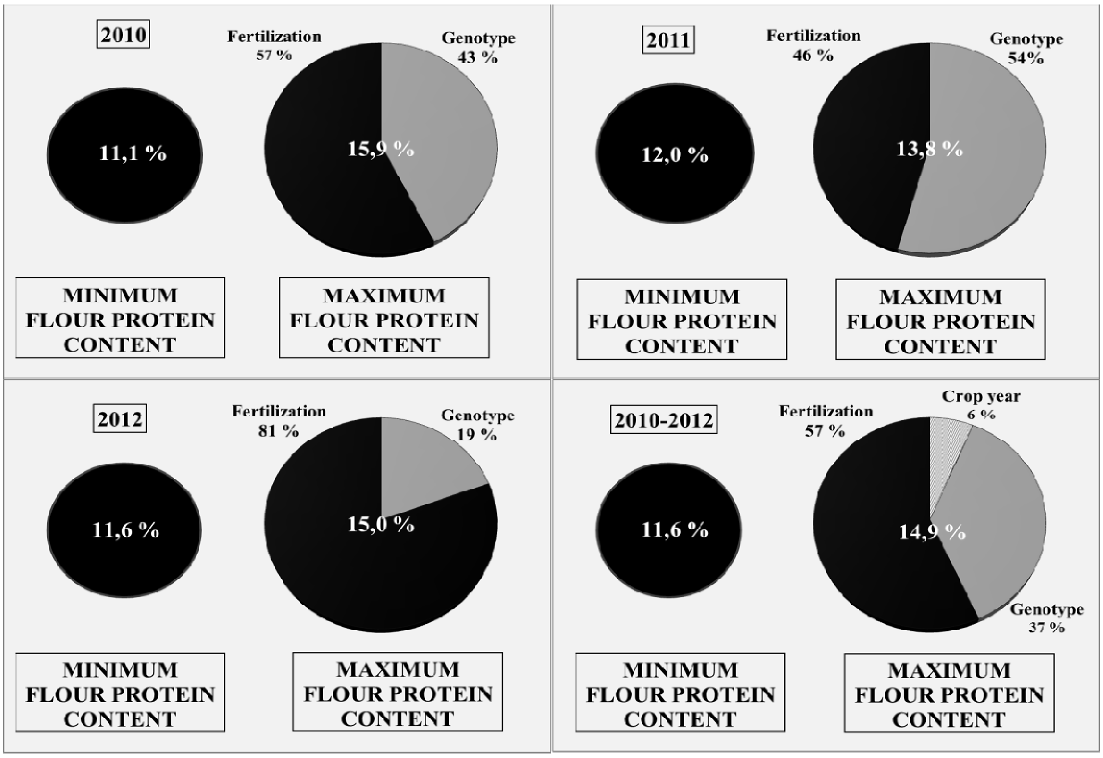

Figure 11. **The significance of the studied factors in determining the flour protein content of the winter wheat**

(Debrecen, 2010-2012)

In crop year 2012, on control plots, the average maximum flour protein content of the yield was 11.6%, compared to which the average of maximum flour protein contents (15.0%) was 3.4% higher. In 2012, the genotype contributed to the difference in increase in only 19%, in contrast with the increase of nutrient dosages, which caused 81% in the formation of higher flour protein content values. Due to the crop year different from the optimum, again the adequate nutrition played the major role. In average of three years, compared to the control treatment (11.6%), 3.4% increase was achieved by the varieties at the optimal N_{120}+PK nutrient level (14.9%). The effect of the crop year on flour protein content values was the lowest: only 6%, the genotype, similarly to the wet gluten content values, affected maximum values of flour protein content in 37%, and nutrient supply had the most significant effect (57%). Evaluating the years even together or separately, it was found that, although three completely different crop years were tested, the protein content values were only slightly different, even despite the different environmental conditions. The genetic potential of the varieties can be more observed in the average crop year, while the appropriate level of nutrition is the most important factor in the development of high flour protein content.

Analyzing the results gained from the experiment together, it can be concluded that the different crop years and environmental conditions affect the yield the most, and they influenced the valorigraphic value and the wet gluten development to a lesser extent. To the different environmental conditions the protein content responded the least. The genotype of the varieties participated in the development of the yield in smaller part (22%) than in the valorigraphic value, wet gluten and protein content of the flour (8-37%), where the genotype plays a more significant role. Role of genotype in the development of the maximum values, in average or optimal environmental conditions, had a greater effect. The maximum weight in each of the three studied factors the nutrient supply had (52-92%), as even for varieties which have a good biological base, it is essential to ensure the proper nutrient supply, in order to make them achieve good results. The nutrient treatment had significant buffering effect, thus could compensate, especially in case of quality parameters, even the extreme environmental effects.

5. NEW SCIENTIFIC RESULTS

1. 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. 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.
2. Varieties GK Öthalom (b = 0.607), Lupus (b = 0.0197) and Mv Toldi (b = 0.5997) can be considered as stable, but produced similar yields even with different, sometimes even extreme ecological conditions. Genius showed a moderately stable (b=0.7644) result, the least stable (b=1.3964) proved to be variety Pannonikus, which in less favorable crop years, could achieve only lower yields, but in more favorable ecological conditions, it could produce high yields.
3. It can be concluded that stability of the control and the N_{30-60}+PK nutrient treatments proved to be the most favorable (b=0.0002-0.4355). The N_{90-150}+PK nutrient doses showed a significantly lower stability (b=0.9722-1.5283), on these nutrient levels yield changed depending on the crop years, but still, the highest maximum yields were realized with these nutrient doses.
4. The best quality was achieved at N_{120}+PK nutrient level. Crop year 2010 with its major precipitation and in 2012, larger amounts of precipitation in the generative phases proved to be the most favorable. In 2011, as a result of drier weather in the generative phenophases, values of quality characteristics had worsened.
5. The genotype significantly determined the chlorophyll content, the leaf area and leaf area duration value. The nutrient supply increased the chlorophyll content, the leaf area and the leaf area duration, the varieties were able to reach higher maximum values.
6. Between the yield and the chlorophyll content a strong significant relationship (r=0.460 to 0.678) was found. The strong nature of this relationship was nearly the same degree from shoot formation till the beginning of wax-ripening. Between yield and leaf area a very strong significant correlation was proved. This relationship was particularly strong (r=0.715-0.768) during flowering and grain filling periods.
7. The valorigraphic values and the SPAD values showed a moderately strong significant correlation (r=0.357-0.446) only from shoot formation till flowering. Between the leaf area index values and the valorigraphic values correlation was significant

(r=0.362-0.444) at each measurement date. The wet gluten content showed strong and moderately strong correlations with the SPAD values, the leaf area index values and the leaf area duration (r=0.436-0.601). In case of protein content the correlation with SPAD values and the leaf area index values was strong and moderately strong significant (r=0.322-0.633).

8. 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%. The valorigraphic values were affected the most by the nutrient supply (71%), variety contributed to it only in 23%. The crop year effect was the lowest (6%) in case of valorigraphic values. The increase in the wet gluten content was due to the genotype in 31%, and to the nutrient supply in 56%, while the crop year played only a 13% role in it. The effect of the crop year on the flour protein content values was only 6%, the genotype affected the flour protein content in 37%, and to the highest extent (57%) the nutrient supply influenced it.

6. SCIENTIFIC RESULTS UTILIZABLE IN THE PRACTICE

1. 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.
2. The Genius and Pannonikus varieties have good nutrient utilization ability and fertilizer response, even in spite of varying crop year effects. These varieties proved to be the most favorable in the practice.
3. In all the three crop years, the N_{120}+PK nutrients dose proved to be optimal in terms of quality parameters. The tested varieties can be categorized in three groups based on the achieved indicators: GK Öthalom had low average yield and average quality parameters, Genius, Pannonikus and Lupus had excellent average yield and quality, Mv Toldi could be characterized by good average yield and excellent quality.
4. In the practice is the most favorable, if the winter wheat could persevered the assimilation capacity as long as it could. If a wheat variety loose its chlorophyll content to after flowering and during grain filling period, and its leaf area index is reduced to a lesser extent, and shows a higher leaf area duration, due to the its higher assimilation capacity it will be able to realize higher yield results.
5. Among the quality values the valorigraphic value showed a weaker correlation with physiological properties. The wet gluten content and protein content of the flour showed a very strong correlation with chlorophyll content and leaf area index. The relationship between the studied parameters was the most powerful during flowering, thus if they are examined in that phenophase it makes prediction more easier.
6. The genotype participates in producing higher yields to a lesser extent (22%) compared to its effect on valorigraphic values, wet gluten content and flour protein content (23-37%), where the genotype has a major role. Role of the genotype in forming the maximum values of quality is enforced better in average or optimal environmental conditions (6-26%). Nutrient supply had the most important role (52-71%) in case all the four factors.

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