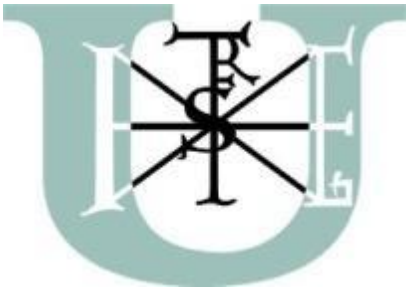

SZENT ISTVÁN UNIVERSITY

Experiments of winter wheat varieties for selection of appropriate varieties to the region

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1. INTRODUCTION AND OBJECTIVES

Rapid growth in the world's population requires more and more food to be produced, and the role of wheat is significant in it. The wheat is cultivated in nearly 70 countries around the world, where the production area is around 220 million hectares in the last 10 years. The average yield from the 1960s to the present has been steadily increasing, which can be explained by rising of intensity of production and the cultivation of varieties with better productivity. In the crop production of our country the cultivation of wheat also plays a decisive role, its acreage occupies one quarter of the arable, it is grown at 1-1.2 million hectares. In 2016, the national average yield reached 5.37 t ha^{-1}, which exceeded the EU average (5.29 t ha^{-1}). In the same year the produced quantity of wheat was 5-5.5 million tonnes, whose more than half (2.76 million tonnes) was exported.

During the last decades, the most challenges in wheat growing in Hungary are the extreme weather conditions, which make it difficult and uncertain in agricultural production. Extreme crop years are becoming more frequently, causing significant fluctuation in the yield. In wet Transdanubian areas higher yields, while lower yields but better quality, in the arid areas of the Great Plain, are observed. Varieties of wheat do not respond to the different ecological conditions in the same way, they have variant amounts and qualities of the yield due to their various adaptability. The results of varietal comparative experiments set up in different locations, can provide help to farmers in the variety selection.

The varietal comparative experiments of different crops (among them the winter wheat) were started in 1994 in the Eszterházy Károly University predecessor institutions in its Tass-puszta Model Farm. I have latched on to this experiment in 1995 as a scientific student of the college and I worked in it till the completion 2006. In my dissertation I evaluated the results of the experiment between 2001 and 2005.

My objectives were:

- testing of features of the winter wheat varieties involved in the experiment at the Mátra-region;
- analysis of the effects of factors, which influence the amount and quality of the yield at the Mátra-region;
- proposition for the suggestible varieties for production at the region according to the results of the experiment;
- the test of the emergence of the productivity according to the results of the winter wheat varietal comparative experiments set in the different area of the country.

My research hypotheses are the following:

H1: The examined agronomic features of the main wheat varieties have effect on the amount of the yield.

H2: The examined agronomic features of the main wheat varieties have effect on the quality of the yield.

H3: At Mátra-region the effect of the crop year influences the amount of the yield of winter wheat significantly.

H4: At Mátra-region the effect of the crop year influences the quality of the yield of winter wheat significantly.

H5: The best performed varieties at the Mátra-region can be chosen according to the results of the varietal comparative experiments.

H6: Suggestible varieties for production in the different region of the country are different according to the results of the varietal comparative experiments.

2. MATERIALS AND METHODS

2.1. Introduction of the experiment

Our experiment was carried out in the Eszterházy Károly University predecessor institutions in its Tass-puszta Model Farm, on A14 plot, on small parcels, in random block arrangement, in four replications. The applied agricultural technics were equal. The soil type of the experiment was chernozem brown forest soil, with medium nitrogen, phosphorus and good potassium content (Table 1.).

Table 1. The results of soil analysis (Gyöngyös, Tass-puszta, A14 plot)

Designation	Values
Plasticity (K_A)	43
pH (KCl)	6.2
Humus (%)	2.3
AL-P_2O_5 (ppm)	99
AL-K_2O (ppm)	249
$CaCO_3$ (%)	0
Salinity (%)	0.01

Source: Own editing

The amount of precipitation in the experimental period and the average temperature were continuously recorded (Figure 1-2.). Considering the amount and the distribution of the precipitation, the 2001 was ranked as an average year, the 2002 and 2003 were droughty years, while the 2004 was favourable and the 2005 was average-good year. In 2003 in the winter period the precipitation was enough for the wheat, but it was followed by a markedly dry spring, which balked the tillering and the stem elongation. The precipitation in June was only 7.2 mm instead of the required 30-40 mm. The effect of the lack of precipitation in May

and June was increased by the temperature above the average. In July we measured high amount of precipitation, which came after the harvest period in Tass-puszta, so the harvest was not balked. In the crop year of 2004 the amount and the distribution of the precipitation gratified the water demand of the wheat.

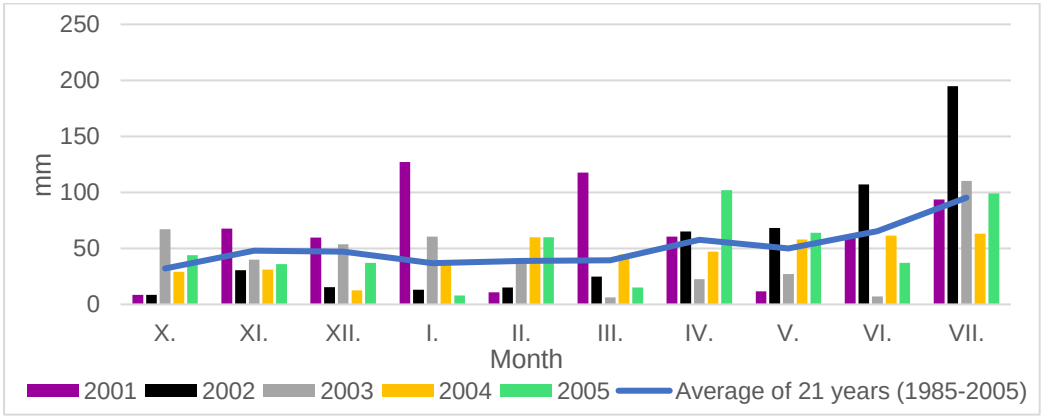

Figure 1. Precipitation (mm) in the studied growing seasons (Gyöngyös, Tass-puszta)
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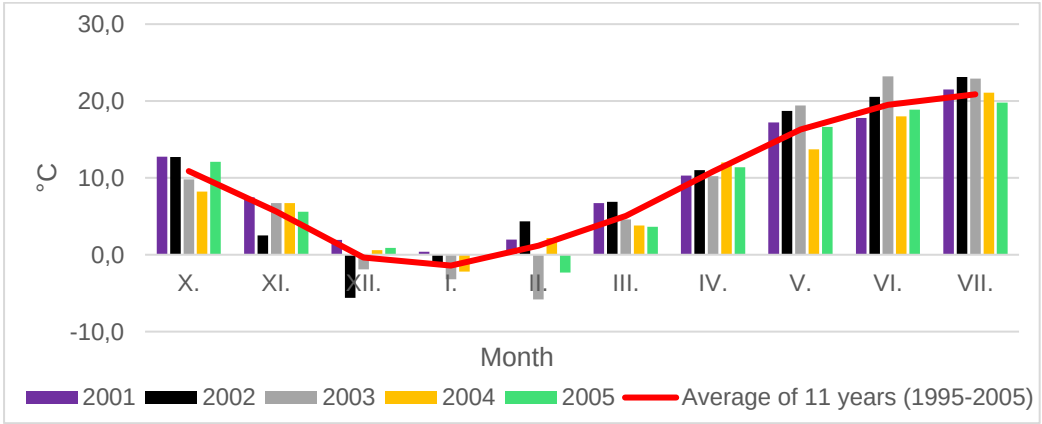

Figure 2. Temperature (°C) in the studied growing seasons (Gyöngyös, Tass-puszta)
Source: Own editing

In my dissertation, I evaluated the results of 11 varieties from the early maturity-13 of the medium- and 6 from the late maturity group, which were included in the experiment in each of the five years (2001-2005).

2.2. The features of the other experiments

I used the results of the winter wheat varietal comparative small-plot experiments carried out in Debrecen, Szeged and Szombathely in the same period with the same conditions to compare the yield of the varieties in different production sites. The publications of the National Institute for Agricultural Quality Control, Cereals, Results of tests on state recognised varieties (2001; 2002; 2003; 2004; 2005) were used as a secondary database.

2.3. The methodology of the analysis and the evaluation of the results

The yield and the wet content of the varieties were measured in four replications. Later the wet content was standardized to 14.5% and the yields were calculated to t ha^{-1}.

The quality tests were made in the Laboratory of Fleischmann Rudolf Research Institute according to the valid standards.

Microsoft Excel 2013 software was used for the recording of the data. The used statistical software were Microsoft Excel 2013 and IBM SPSS Statistics 20 for Windows. The statistical evaluations were carried out by one and two factor variance analysis, Tukey-b test, Pearson's correlation analysis and Kang's stability analysis.

3. RESULTS

3.1. Study of the agronomical features of the varieties

The evaluations of the agronomical traits of varieties were made severally and it can be found, that in the different maturity groups there was not so variety, which gave excellent results in all examined traits (Table 2.).

The Hagberg's falling number was not marked in the table, because the too low and high rates both are disfavourable, therefore the average counted from the results of some years can offer false information. The falling number is an extremely sensitive and complicated index, as it has a quality-feature part, which is determined by the amount of the enzymes, while the other part by the activation of the enzymes. It responds immediately to the weather changes before the harvest, since it reacts with significant decrease to the large precipitation fallen before the harvest, so the method of the evaluation is different from the other quality indexes. It is an important parameter in trade, but referred to the previous sentences its change has to be examined in the knowledge of the precipitation data (GYŐRI – GYŐRINÉ 1998, JOLÁNKAI – SZABÓ 2005).

Table 2. Sorting of the varieties with the best and smallest results in the experiment according to the agronomical traits in the average of the examined 5 years

Agronomical trait	Variety with the best result	Variety with the smallest result
Early maturity group		
Winter hardiness	GK Garaboly (7.9)	Abony (6.9) Alföld 90 (6.9) GK Verecke (6.9)
Lodging resistance	Mv Palotás (8.5)	Alföld 90 (7.5) Kompolti 3 (7.5)
Plant height	Abony (88.4)	GK Élet (70.2)
Thousand seed weight	Mv Emese (42.2)	Kompolti 3 (37.3)
Hectolitre weight	Mv Palotás (79.6)	GK Öthalom (75.5)
Grain yield	Flori 2 (5.99)	Alföld 90 (4.89)
Crude protein content	Mv Palotás (15.5)	GK Kalász (13.8)
Wet gluten content	Mv Palotás (34.1)	GK Kalász (30.9)
Sedimentation index	Mv Palotás (59.6)	Flori 2 (46.5)
Medium maturity group		
Winter hardiness	GK Cipó (7.7) GK Petur (7.7) Mv Csárdás (7.7)	Róna (7.1)
Lodging resistance	Mv Csárdás (8.7)	MF Kazal (7.9)
Plant height	Rusija (85.2)	Buzogány (69.6)
Thousand seed weight	Róna (42.7)	Hunor (37.5)
Hectolitre weight	Mv Csárdás (78.4)	Buzogány (75.5)
Grain yield	Buzogány (6.14)	GK Miska (4.96)
Crude protein content	Rusija (15.2)	MF Kazal (12.0)
Wet gluten content	Mv Csárdás (33.4)	MF Kazal (25.8)
Sedimentation index	GK Petur (58.3)	MF Kazal (41.4)
Late maturity group		
Winter hardiness	Maximus (7.6)	Carlo (7.1)
Lodging resistance	Mv Magdaléna (8.5)	Carlo (7.8)
Plant height	Ludwig (93.0)	Mv Magdaléna (78.0)
Thousand seed weight	Mv Magdaléna (40.1)	Gaspard (36.9)
Hectolitre weight	Mv Magdaléna (79.4)	Gaspard (76.4) Maximus (76.4)
Grain yield	Maximus (5.81)	Carlo (4.97)
Crude protein content	Capo (15.2)	Maximus (14.1)
Wet gluten content	Capo (35.2)	Ludwig (31.1) Maximus (31.1)
Sedimentation index	Ludwig (57.6)	Gaspard (49.8)

Source: Own editing

In the early maturity group the Mv Palotás gave excellent performance especially in the quality features, moreover it also had the best lodging resistance and hectolitre weight in its maturity group, but according to the grain yield the Flori 2 was the most remarkable. The Alföld 90 variety was the weakest in more

features as the winter hardiness, lodging resistance and grain yield, which is the most important feature for the farmers.

In the medium maturity group the Mv Csárdás obtained the best results in the most features as winter hardiness, lodging resistance, test weight, wet gluten content, but the Buzogány gave the highest yield. The MF Kazal also in four traits was the worst (lodging resistance, crude protein content, wet gluten content, and sedimentation index).

In the late maturity group the Mv Magdaléna achieved very good results in three features as lodging resistance, thousand seed weight, test weight, while plant height of it was the smallest in the group. The least favourable results in more characteristics were given by Maximus, Gaspard and Carlo varieties.

3.2. The evaluation of the interaction between the results of the phenological investigations and the yields

The interaction between the results of the phenological investigations and the yield was evaluated by Pearson's correlation analysis, which shows the direction and the strength of the interaction. The strongest, positive connection was confirmed by the correlation analysis between the winter hardiness and the grain yield (0.843). In the studied years big variance can be found in the plant height owing to the decided difference in crop years. Between the plant height and lodging resistance a negative, medium correlation (-0.409) was found, which was significant. The wheat plants with longer stem are more susceptible to lodging if they do not have strong stem stability. The correlation analysis showed strong, positive interaction between the plant height and the grain yield (0.709), which verifies, that the higher, more developed plants have larger biomass-weight, and it contributes to the increase of the amount of the yield. The correlation analysis showed negative interactions between the examined quality parameters and the winter hardiness and the plant height, while between the quality parameters and the lodging resistance positive correlation was found. The strongest connection was signed between the winter hardiness and the crude protein content (-0.669). The weakest, not significant interaction was between the lodging resistance and the wet gluten content (0.148).

The length of the vegetation period can be relevant in the yield in terms of the weather factors, because the amount of the precipitation and the temperature appropriated in the given periods of the development are different in regions, so the necessary conditions are not given always. The longer vegetation period with advantageous weather conditions can afford possibility for larger dry matter accumulation and hereby for the higher yield for the varieties. However on those areas where the summer is hot and dry the varieties with shorter vegetation period can be offered. Positive, medium interaction (0.425) was found in Tass-puszta between the length of the vegetation period and the average yield, thus in Mátra-

region the varieties with longer vegetation period gave significantly higher yield in the average of the studied years.

The correlation analysis signed negative correlation between the length of the vegetation period and all the quality parameters. The strongest, negative connection was found between the days until ripening and the crude protein content of the varieties (-0.553), but also significant, medium interaction was in the case of the wet gluten content (-0.440) and the sedimentation index (-0.437). The correlation between the Hagberg's fallen number and the length of the vegetation period was not verifiable (-0.097).

Positive significant correlation with different strength was found between the studied quality indexes. The strongest connection was appeared between the crude protein content and the wet gluten content (0.938), which confirmed the research results of KASSAI et al. (2006), that positive interaction was found between the protein content and the wet gluten content.

The correlation between the sedimentation index and the crude protein content (0.928) as well as between the sedimentation index and the wet gluten content was strong. The slightest interaction was found between the Hagberg's fallen number and the other quality parameters, but also they could be listed into the strong (above 0.5) category. Hereby my research results disconfirm those results of MATUZ et al. (1999), that the falling number did not have correlation with any quality parameters.

Based on the results of the experiment, it was proved in Mátra-region, that there was a negative correlation between the quality indexes and the average yield. The closest correlation was between the average yield and the crude protein content (-0.866), followed by the average yield and the sedimentation index (-0.838), as well as the average yield and the wet gluten content (-0.792). The weakest interaction was shown by the correlation analysis between the average yield and the falling number (-0.533), but it is still in the close category.

3.3. Analysing the effects of the influential factors for the amount and the quality of the yield in the Mátra-region

Beyond the agrotechnical factors the two most important factors influencing the yield of the wheat are the climatic conditions, their variability and the genetic potential of the variety.

3.3.1. Evaluation of the effect of the crop year

Based on the results of the researches carried out during the experiment, it can be clearly seen, that in the values of different agronomical traits, such as plant height, lodging resistance, average yield there is a noticeable difference between the results of each crop year, for which different weather conditions are probably responsible. In unfavourable year, the values of the average yield reached only 28-30% of the average yield of the favourable year, which is illustrative of all the

three maturity group. In order to prove the influence of the effect of the crop year on the yield, the two-factor variance analysis with replications was used for each maturity group in relation to the average yield.

Based on the data of the variation tables (Table 3.), it can be concluded, that the calculated F-values in all three maturity groups are far above the F-value in the table (critical F value) and the p-value is below 0.05, which means that there is significant difference between the average yields of the years at 95% confidence level, so the effect of the crop year has statistically verifiable influence on the average yield of the wheat varieties at the experimental site.

Table 3. Variation table based on the two factor variance analysis (with replications)

VARIANCE ANALYSIS							
Maturity group	*Source of variation*	*SS*	*df*	*MS*	*F*	*p-value*	*F crit.*
Early	Year	1042.5914	4	260.6479	456.533	0.0000	2.4180
	Variety	16.1777	12	1.3482	2.3613	0.0074	1.8021
	Interaction	50.0467	48	1.0426	1.8262	0.0023	1.4232
	Within	111.3311	195	0.5709			
	Total	1220.1470	259				
Medium	Year	966.6204	4	241.6551	875.5787	0.0000	2.4264
	Variety	14.1639	10	1.4164	5.1320	0.0000	1.8885
	Interaction	22.3802	40	0.5595	2.0272	0.0011	1.4679
	Within	45.5391	165	0.2760			
	Total	1048.7040	219				
Late	Year	487.0043	4	121.7511	367.4675	0.0000	2.4729
	Variety	8.5095	5	1.7019	5.1367	0.0003	2.3157
	Interaction	18.2709	20	0.9136	2.7573	0.0006	1.6883
	Within	29.8192	90	0.3313			
	Total	543.6039	119				

Source: Own editing

The quality parameters were not determined by replications, therefore I could not perform the two-factor analysis (with replications), so I used the Tukey-b test to prove the effect of the crop year (Table 4.).

For the crude protein content, the results of 2002 and 2003 were similar, while the 2004 and 2005 years differed significantly from each other and from the 2002 and 2003 years. Based on the wet gluten content all years were significantly different. Based on the sedimentation index the 2004 and 2005 years were significantly different from each other and from the 2002 and 2003 years, however the effect of the crop year did not cause significantly verifiable difference between the results of 2002 and 2003 years. In the case of the Hagberg's falling number, the results of 2005 and 2004, as well as of 2002 and

2003 are similar, while the Tukey-b test verified significant difference between 2005-2004 and 2002-2003.

Table 4. The results of the Tukey-b test for the quality parameters (2002-2005) (the order of the years is increased from up to down according to the value of the quality index)

Year		N	Significance level = 0.05			
			1	2	3	4
Tukey-b crude protein%	2004	30	11.250			
	2005	30		13.297		
	2002	30			16.213	
	2003	30			16.440	
Tukey-b wet gluten %	2004	30	23.030			
	2005	30		27.003		
	2003	30			36.073	
	2002	30				40.663
Tukey-b sedimentation-index	2004	30	38.933			
	2005	30		45.833		
	2002	30			63.360	
	2003	30			65.640	
Tukey-b Hagberg's falling number	2005	30	343.00			
	2004	30	352.80			
	2002	30		466.73		
	2003	30		476.30		

Source: Own editing

Based on the results of the Tukey-b tests, it can be concluded that the effect of the crop year in the Mátra-region causes a statistically verifiable difference in the quality indexes of wheat varieties. The years 2002 and 2003 were favourable for all the quality parameters of the winter wheat, but falling number of them was outstanding.

3.3.2. The effect of meteorological parameters on the development, yield and quality of the wheat

Pearson's correlation analysis was used to measure the effect of meteorological parameters, and the effect of the precipitation and the average temperature was examined. Since the distribution of the precipitation in vegetation period has very important role next to the amount, I divided the cumulative values of the vegetation period to the main phenological phases of the development of the wheat.

There was a close positive correlation (0.520) between the amount of the precipitation of the vegetation period and the plant height of the wheat. The strongest impact for the growth of the wheat plant was the amount of precipitation falling in March-April, the correlation coefficient (r) is 0.615, which shows a

significant, close, positive interaction. In addition, the amount of the precipitation in early-summer period was also strong, positive correlation with the plant height (0.576).

There was a moderate, positive correlation (0.352) between the amount of precipitation in the vegetation period and the average yield of the wheat. The amount of precipitation falling in the second half of the vegetation period has a positive effect on the yield, the correlation is medial (0.413) between the precipitation of spring and the average yield.

The average temperature of the vegetation period had a medium, negative connection with the plant height (-0.403). There was very strong positive correlation between the average temperature of the winter and the plant height (0.744), which can be caused by the strong, long lasting cooling off, which often occurs at the end of winter in Mátra-region. The strongest negative effect for the plant height the early summer temperature has (-0.748). In our experiment the average temperature measured during the vegetation period had a strong negative (-0.603) effect on the yield of the varieties. With the exception of the average temperature of winter, the negative correlation also existed with other periods of the vegetation period, but their strengths were different. The average temperature of winter had strong positive influence (0.659) on yield, while the temperature of early-summer period had very tight negative effect (-0.932).

Based on our results, the higher yields in the Mátra-region are provided with a mild temperature ensuring good wintering, large spring-early summer precipitation, promoted the tillering and stem elongation and the lower early summer temperature. The results of my research confirm those results of ÁGOSTON (2009) received in Debrecen, that the spring precipitation and the early-summer temperature have significant influence on yield of the wheat.

I found negative correlation between the amount of precipitation and the examined quality indicators (crude protein, wet gluten, sedimentation index, Hagberg's falling number), which was medium (-0.479) for the crude protein content and close (0.5<) for the other indicators. Examining the different phases of the vegetation period, the strongest negative impact on quality had the amount of spring precipitation, wet gluten content was influenced in the smallest (-0.421) extent, while sedimentation index was influenced in the strongest (-0.583) extent by it. In addition, the amount of precipitation of winter had significant effect on the wet gluten content (-0.352).

The strongest correlation between the average temperature of the vegetation period and the wet gluten content (0.812) was found, but in order it also had very strong effect on the sedimentation index (0.740) and the crude protein content (0.716). The weakest, but still close category of interaction was found with the Hagberg's falling number (0.595). The most significant effect within the vegetation period was the early-summer temperature, I found close interaction

with the Hagberg's falling number (0.558) and very close interactions with the other parameters (0.790-0.883). The strongest positive correlation could be found between the early-summer temperature and the crude protein content (0.883).

To sum it up, it can be stated, that the higher precipitation has a negative effect on the quality indicators, while the higher temperature of the vegetation period has positive effect on it, which confirmed the results of KOLTAY – BALLA (1982) and AMBRUS (2016), that the droughty weather has a favourable effect on the quality of the wheat.

3.4. Complex evaluation of the results of the winter wheat varieties included in the experiment

For the complex evaluation of varieties included in the experiment should take into account their yield, quality indicators and the adaptability. The yield stability, the complex evaluation of the quality indicators, the quality stability of the varieties have been determined, and by compering these values to the average, the varieties performed above the average can be selected.

3.4.1. Evaluation of the Kang's stability of wheat varieties included in the experiment

To the analysis of the yield stability of the examined wheat varieties I used the Kang's stability analysis, which helped me to analyse the interaction in five years between the average of the effect of crop year and the genotype. During the stability analysis, the yields of the varieties were graphically represented by linear regression. Based on the analysis of the regression line and its associated formula, the line with the smallest slope gives the most stable variety. Furthermore, the value of R^2 shown in the diagram gives the accuracy of the line's fit, which means, that how the examined factors influenced the formation of the crop and how it was determined by other factors.

The R^2 values in the analysis of yield stability were high with the exception of Alföld 90 variety (0.7992), so in spite of the fact that the studied five year period is not very long, the evaluation can be considered reliable, and the decided difference between the crop years also contributed to it.

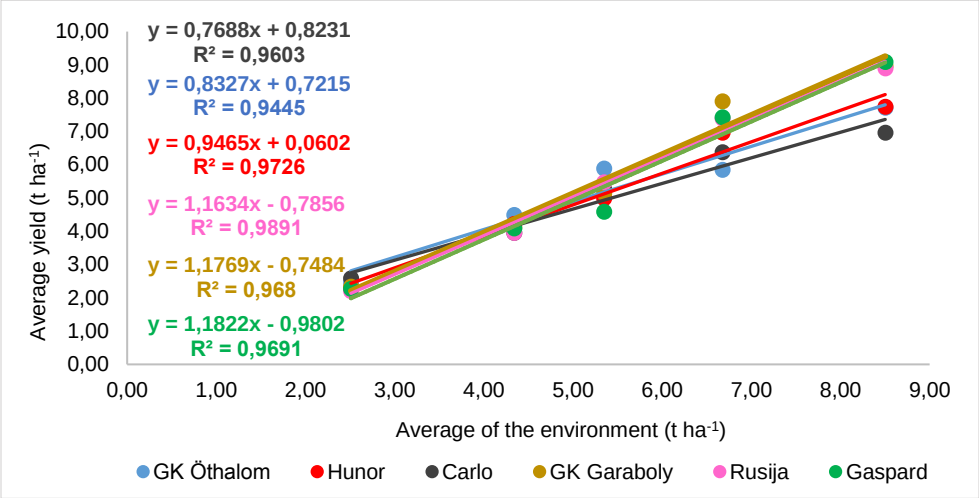

Figure 3. The yield stability of the wheat varieties with the best and weakest results of the maturity groups
Source: Own editing

Based on the value of the linear regression coefficient, the varieties were ranked by maturity group, the following are the most stable on the basis of the average yield (Figure 3.):

- in the early maturity group: GK Öthalom (0.8327; average yield: 5.13 t ha^{-1});
- in the medium maturity group: Hunor (0.9465; average yield: 5.31 t ha^{-1});
- in the late maturity group: Carlo (0.7688; average yield: 4.97 t ha^{-1}).

The varieties most responsive to the effect of the crop year were the following:

- in the early maturity group: GK Garaboly (1.1769; average yield: 7.9 t ha^{-1});
- in the medium maturity group: Rusija (1.1634; average yield: 7.3 t ha^{-1});
- in the late maturity group: Gaspard (1.1822; average yield: 7.2 t ha^{-1}).

3.4.2. The complex evaluation of the quality of the studied wheat varieties

The complex assessment of the quality of wheat varieties is a difficult task, since it can be executed by in light of several parameters together. Using the Győri's Z-index created by GYŐRI – SZILÁGYI (1999), I compared the winter wheat varieties included in the experiment with the available quality parameters (crude protein content, gluten content, sedimentation index, Hagberg's falling number), thus the maximum score can be 100. On the basis of the obtained Győri's Z-index, the complex classification of wheat can be made, 5 categories (low quality, satisfactory, good, very good, excellent) were defined by GYŐRI – SZILÁGYI (1999) for it. The final assessment was made at the rate percent compared to the total score.

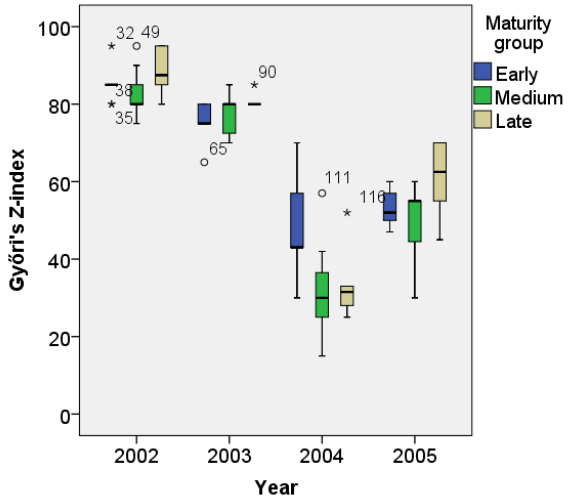

Figure 4. The standard deviation of the Győri's Z-index value of the varieties included in the experiment
Source: Own editing

On the basis of the complex classification of the varieties it can be stated that the quality of the varieties also was significantly influenced by the effect of the crop year. Varieties achieved the best results in the year 2002. We also found good results in the droughty year of 2003, although the vast majority of the varieties got a 'very good' rating. The weakest classification of the varieties was in the 2004 crop year, with the high heterogeneity of the results, which is well indicated by the standard deviation of the data (Figure 4.). The highest variation was found in the early maturity group, and the weakest result was in the late maturity group. The weather of the 2005 crop year was not favourable to the development of good quality, although the data were more homogenous this year. To sum it up, the smallest difference between the varieties was in terms of the falling number, and the biggest difference was caused by the difference in crude protein content and in the gluten content, so these two indicators are mainly responsible for the changes of the Győri's Z-index in the Mátra-region.

Similarly to the average yield data, the performance of the quality parameters is also significantly influenced by the effect of the crop year, and the varieties can be adapted in different ways to it, so the Kang's stability analysis is also justified in this case. To the achievement of the quality stability, the values of the Győri's Z-index of the varieties were taken into account, which were compared to the average of the relevant crop year (environment), and the variety-crop year interactions were graphically represented.

In the evaluation of quality stability, a greater standard deviation of the R^2 values was found than in the case of the average yield, which indicates a less accurate fit of the regression line. The lowest R^2 value was found for the variety Mv Palotás

(0.5457), while for the other genotypes the standard deviation was between 0.7936 and 0.9965, so the fitting of the line is still reliable for the evaluation.

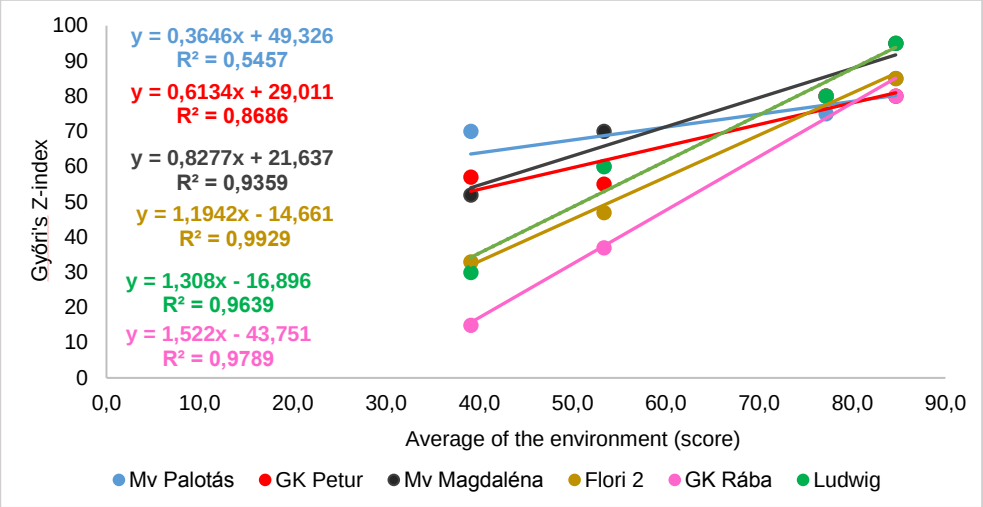

Figure 5. The quality stability of the wheat varieties with the best and weakest results of the maturity groups
Source: Own editing

Based on the value of the linear regression coefficient, the varieties were ranked by maturity group. The varieties with the best quality stability were (Figure 5.):

- in the early maturity group: Mv Palotás (0.3646; Z-index: 73);
- in the medium maturity group: GK Petur (0.6134; Z-index: 68);
- in the late maturity group: Mv Magdaléna (0.8277; Z-index: 74).

The varieties most responsive to the effect of the crop year were the following:

- in the early maturity group: Flori 2 (1.1942; Z-index: 61);
- in the medium maturity group: GK Rába (1.522; Z-index: 53);
- in the late maturity group: Ludwig (1.308; Z-index: 66).

3.4.3. The complex classification of the studied varieties in the Mátra-region

To facilitate variety selection, the different traits of the varieties have to be studied together, for it I have graphically represented the yields of the varieties and the quality based on the Győri's Z-index points by maturity group (Figures 6-8.).

The graph in the figure is divided into four parts by means of a line indicating the average of the yields and the Z-index of the studied varieties. The varieties, which have high yields and good quality (above the average) of the examined years are in the top right corner of the chart, but varieties with higher yield and lower quality in the top left corner, with lower yield and higher quality are in the lower right corner. Cultivating the varieties from the lower left corner is not recommended in our area as their yield is small, which is combined with poor quality.

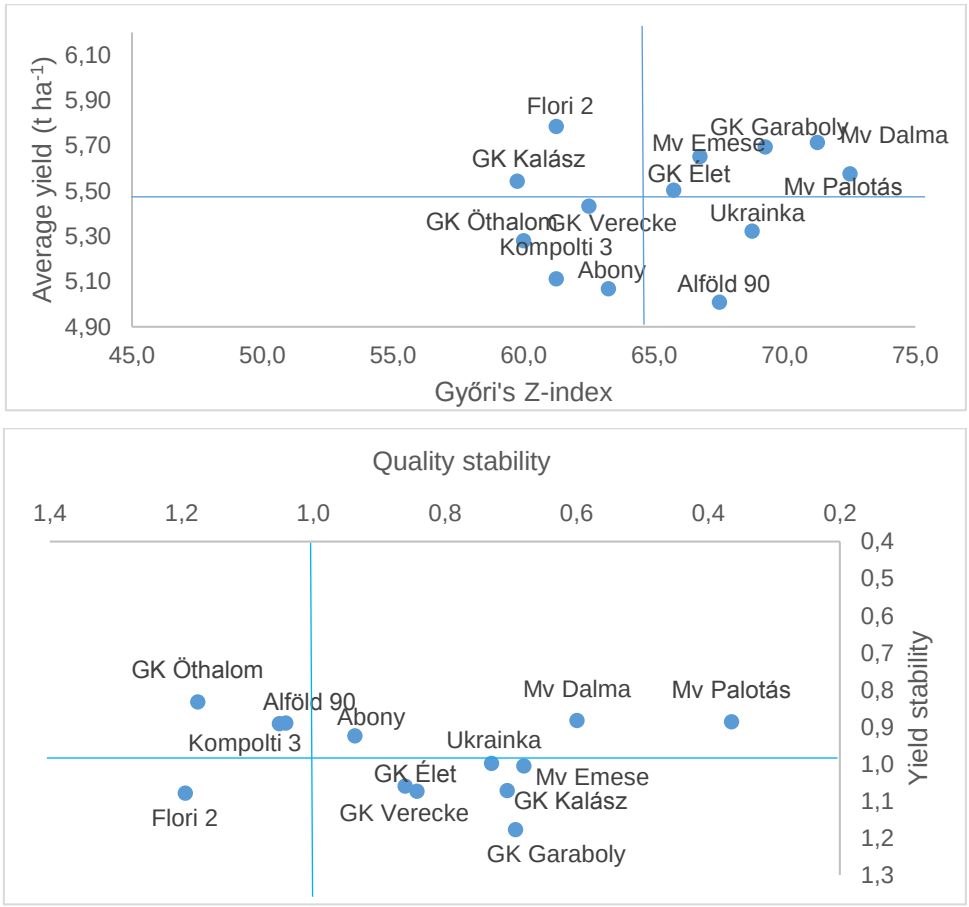

Figure 6. The complex classification of the varieties of the early maturity group
Source: Own editing

Next to the previous features for the variety selection, the yield and quality stability of the variety is also important, therefore the stability values determined by Kang's stability analysis, and the graphical representation of the regression coefficients, were also made by maturity groups. By comparing the two diagrams, a complete information can be got about the expected performance of the variety in a given area.

The best results of the ecological conditions typical of the Mátra-region were achieved by Mv Palotás and Mv Dalma varieties from the early maturity group (Figure 6.), which varieties had yield and quality value and stability together above the average.

The Mv Emese variety was characterized by good productivity and good quality with average stability. The Ukrainka gave good quality next to the medium average yield and it was combined by average stability. The Flori 2 had the highest productivity of the maturity group, with lower quality than the average

and its yield and quality stability remained under the average, sot the variety reacted in a very sensitive was to the effect of the crop year. The GK Öthalom and Kompolti 3 varieties did not reach the average of the studied varieties in terms of yield and quality, but their average yields were kept well under different weather conditions, however their quality stability was weak. The Abony variety was poor in terms of yield and quality, but it was combined by good stability.

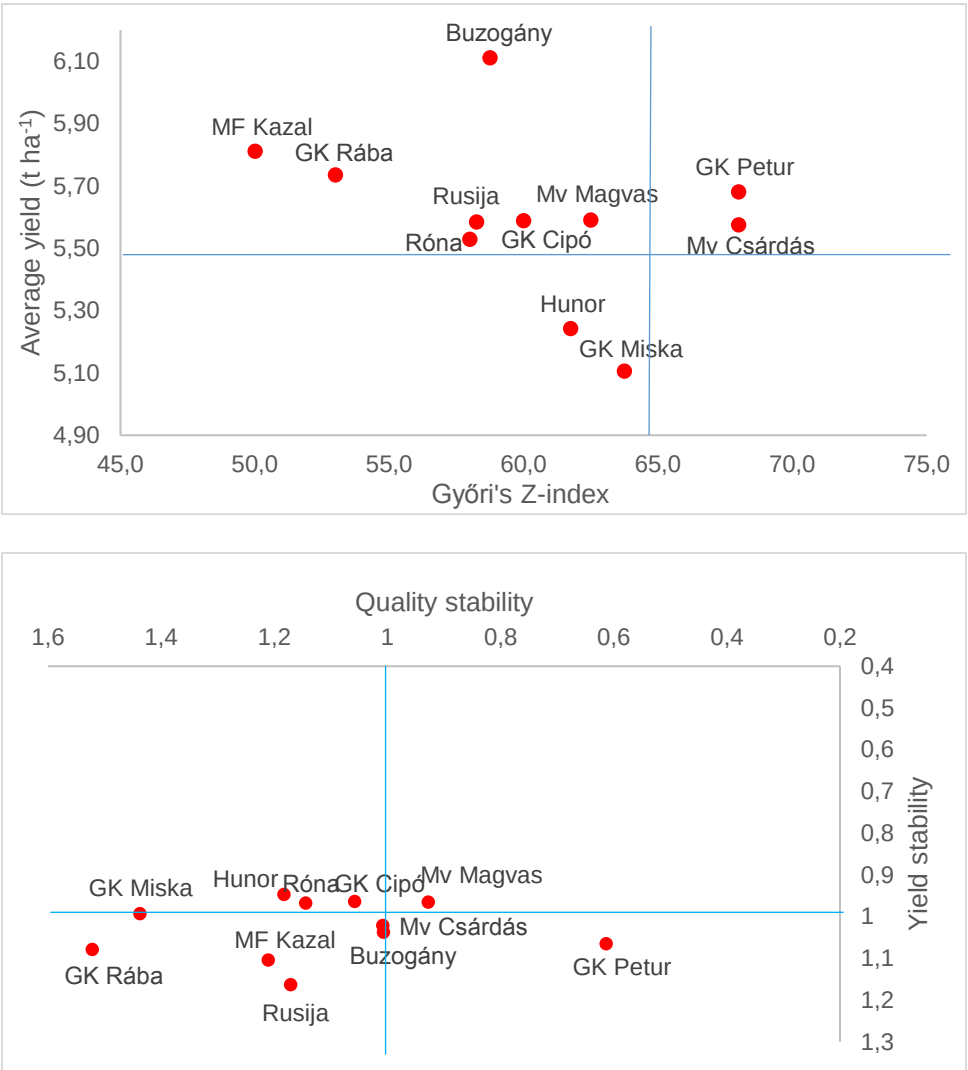

Figure 7. The complex classification of the varieties of the medium maturity group
Source: Own editing

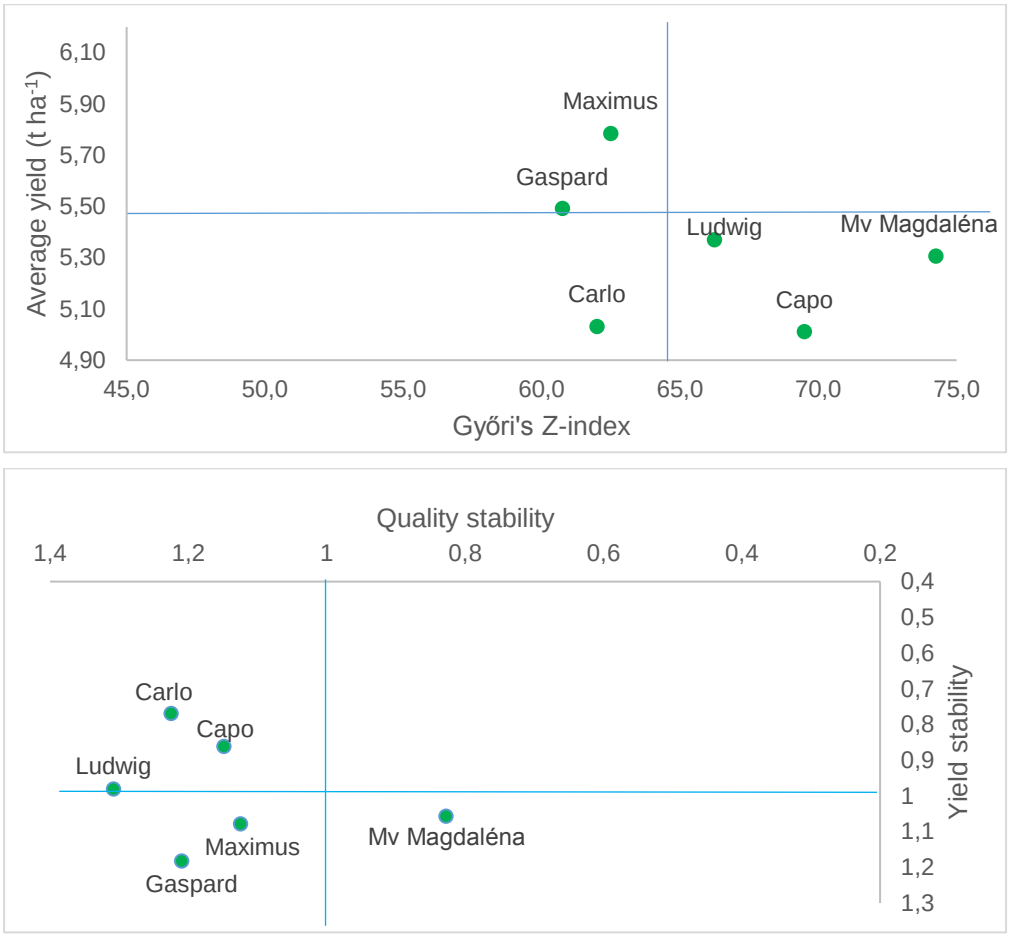

Figure 8. The complex classification of the varieties of the late maturity group
Source: Own editing

The majority of the varieties of medium maturity group were characterized by higher yields and weaker quality (Figure 7.), which they were able to main at different levels of stability. Among the varieties of the medium maturity group only GK Petur and Mv Csárdás had excellent yields and quality, the former with the highest quality stability of the maturity group and under the average of the yield stability. The stability of Mv Csárdás was on average both in terms of the yield and quality. The Buzogány gave an excellent average yield, the quality was slightly below the average, accompanied by an average adaptability. MF Kazal and GK Rába varieties gave high amount of the yield with poor quality, and the stabilities for both values also had problem, so it is not recommended for Mátra-region. Both the Hunor and the GK Miska varieties had yield and quality below the average, which was maintained with average yield stability and very poor quality stability, so their cultivation also is not recommended in the Mátra-region.

In the late maturity group none of our varieties included in the experiment had a high average yield, quality and good adaptability with it (Figure 8.). Mv Magdaléna gave excellent quality next to average yield slightly below the average of the varieties, which has been kept by stability slightly below the average. The quality of the Ludwig variety also exceeded the average value, but it was not well adapted to the ecological conditions of the landscape, and its average yield was also lower than the average of the varieties. The Maximus and Gaspard varieties were able to reach high yields, but their ability to adapt was also weak. If I had to choose among the varieties of the maturity group, I would recommend Mv Magdaléna, which has been still popular among farmers for many years.

3.5. Examination of yield of varieties in different production sites

In order to survey the differences between the ability of the varieties to adapt to different regions and the suitability of Mátra-region for wheat production, the yields of the varieties were compared to the results of the small-plot varietal comparative experiments in other areas of the country (Debrecen, Szeged, Szombathely). In the light of the available data, the two-factor analysis of variance (without replications) was used to evaluate the results, as data in four replicas only in the Gyöngyös production site were available.

Based on the results of the variance analysis by maturity groups, it can be concluded that there is a significant difference between the production sites. However, based on the results of the two-factor analysis of variance carried out together for all examined varieties, there was significant difference between the production sites and also the yields of the varieties.

It can be seen, that in a favourable year flatlands are more appropriate for growing of the wheat, higher yields are realized, but in adverse in droughty years, the cooler, wet, more balanced climate of the mountains can reduce the drought damage.

The analysis of the production site – variety interaction was made with graphical representation, because in the absence of replications necessary for statistical analysis I could not perform the analysis of variance for this area. Based on the figures it can be stated that the orders of the varieties in the studied years are different at the production sites, so there is interaction between the production sites and the varieties, although it cannot be verified statistically in the absence of the replication data.

3.6. The role of the varieties included in the experiment in cultivation

Due to the rapid change of varieties, a significant number of the varieties included in the experiment are no longer in the National List of Varieties and in cultivation. With the emergence of new varieties, the role of previously registered varieties has been decreasing, as it is shown by the reducing proportion of their seed-growing areas and the selection of varieties. The seed of GK Garaboly, which provided reliable yields in our experiment in the early maturity group, was grown

until 2016, occupying 0.2% of the breeding area qualified as suitable. In 2017, GK Kalász and GK Élet were still present in the seed propagation from this maturity group, although their role is decreasing (0.03% and 0.05%). In the medium maturity group, Buzogány, Mv Csárdás and GK Petur varieties with average yield above the average of the varieties in Tass-puszta, have remained in cultivation up till now, and their seeds are produced. In the late maturity group, Mv Magdaléna occupied 0.78% of the wheat seed propagation areas in 2017, representing the highest proportion of the year from the varieties included in our experiment.

The practical usefulness of our experimental results is confirmed by the fact that the best performing varieties in the experiment have remained in cultivation for longer period, which is well indicated by the order of their selection.

3.7. The test of the complex classification model with newer varieties

Some of the varieties evaluated in my dissertation have already been out of cultivation in the course of time, so fresh information about them is not available. So I considered it necessary to apply the complex classification model for the newer varieties. For the evaluation of the newer varieties, the results of the Winter Wheat Postregistragion Varietal Experiments coordinated by the NFCSO (National Food Chain Safety Office) were used.

For the evaluation the data of the Debrecen production site was chosen, as the ecological conditions of it are the most similar to our experiment in Tass-puszta and the data of the yield are available for the 2013, 2014, 2016 and 2017 years. In 2015 the results of the quality tests were not made at the selected production site, so the model cannot be applied for this year. For the selected period, eight varieties of the three maturity groups were found included into the experiment in each year.

2013 and 2016 were rainy (the amount of precipitation during the vegetation period was 542.8 mm and 520.7 mm), while 2014 and 2017 were drier (the amount of the precipitation in the growing season was 308.5 mm and 364 mm) in the studied period.

On the basis of the results of the yields it can be concluded that the 2013 crop year was the most favourable for the production of the winter wheat, while the best quality indicators were got in 2014. For the complex evaluation of the quality parameters the Győri's Z-index created by the crude protein content and the wet gluten content were used. Based on the Kang's stability analysis carried out, there are also significant differences in yield and quality stability.

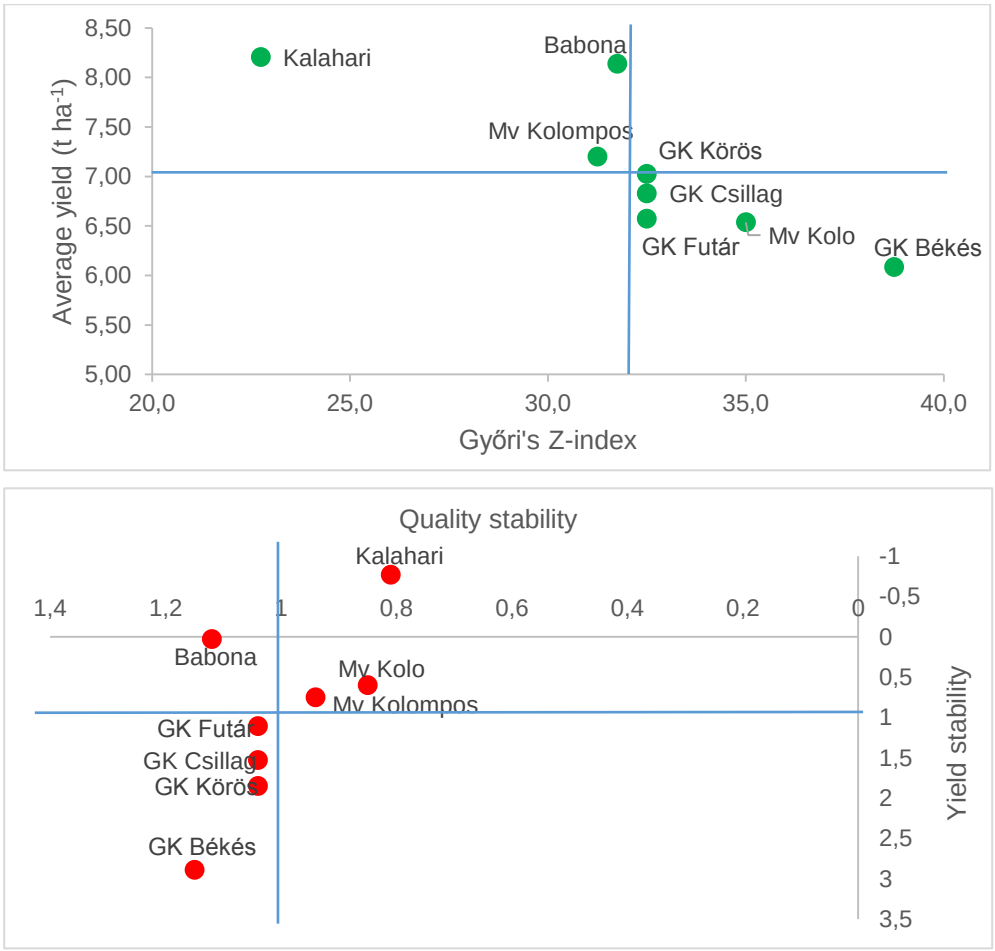

Figure 9. The complex classification of the newer varieties based on the experiment in Debrecen
Source: Own editing

Based on the results of the complex classification model (Figure 9.), none of the varieties had excellent yields and quality. With reference to the attitude of the NFCSO about the secondary publication of the results of the variety experiments coordinated by them, I disregard the ranking and the evaluation with text of the varieties. However, based on the results of the model, the differences between the varieties are well reflected, the varieties suitable for the purpose of cultivation can be well separated and selected, so the complex classification model can be used for the evaluation of the present varieties.

3.8. New scientific results

During my research I received the following new scientific results:

1. Based on the results of the experiment it was proved that there is significant difference between the average yields of the crop years in the Mátra-region in all the three maturity group, so the effect of the crop year has a significant influence on the average yield of wheat varieties. The wintering of varieties is endangered by strong colds at the end of winter, significant reduction in yield is also effected of it, even in a year with favourable precipitation in the crop year. The amount of spring and early summer precipitation above the average with a cooler temperature influences the amount of the yield in a more favourable direction in the region.
2. Based on the results of the Tukey-b tests, the influencing effect of the effect of the crop year on the quality of the winter wheat varieties was statictically proven in Mátra-region, and the temperature above the average in early-summer improves the quality.
3. It has also been confirmed in Mátra-region that the yield is in a negative correlation with the quality of the crop, which is due to their different weather demands.
4. In order to facilitate the selection of wheat varieties recommended for cultivation in the studied area, next to representation of the average yield and the complex quality, a complex classification model was developed by depicting the regression coefficients of the Kang's stability analysis used to evaluation of yield- and quality stability, and compared them to the previous parameters.

Practical results are the following:

1. Our results confirmed those conclusions of NAGY (1981) and ÁNGYÁN et al. (2004) that the soil of the Mátra-region is not the most suitable for the production of winter wheat, as the average yields in favourable years are left behind the yields measured in the lowlands and in the north-western regions of Transdanubia.
2. Based on the evaluation of the results of the experiment, it was found that the best performing varieties remain in cultivation and the weakest ones are selected, therefore the varietal comparison experiment set for regions provide objective, practicable information for the variety selection for the farmers.
3. Based on the results of the varied crop years of the experiment, the highest yields are obtained from the medium or early ripening groups in the Debrecen and the Gyöngyös region, the higher yields can be expected in

the region of Szeged in the medium or late maturity group, while in the Szombathely region the cultivation of early varieties is more efficient.

4. CONCLUSIONS AND SUGGESTIONS

4.1. Conclusions and suggestions

Based on the results of the phenological studies, it was confirmed that the strong cold at the end of the winter is critical for wheat, because the frost tolerance of the wheat, which has already done the vernalization and the loss of dissimilation is reduced, so the stronger frost at the end of the winter can cause the death of the plants.

In the course of growth of the wheat, the varieties in the late maturity group responded the least to the drought in our experiment. The droughty crop year also had a significant negative impact on formation of the thousand seed weight. In the years when the precipitation was higher in June and it was combined with temperature around the average of the area, high thousand seed weights were formed.

There was a big difference in the average yields and the quality parameters in the different years, based on the results of the two-factor analysis of variance and the Tukey-b test, it was statistically confirmed that the effects of the crop year in the Mátra-region had a significant influence on the yields and quality.

On the basis of the aggregate evaluation of the results of varieties, it can be concluded that no variety was found in any maturity group that would have provided the best results for each feature.

Based on the research of the interaction between the agronomical traits it was proved that:

- Between the plant height and lodging resistance a negative, medium correlation was found, which was significant. The correlation analysis showed strong, positive interaction between the plant height and the grain yield, which verifies, that the higher, more developed plants have larger biomass-weight, and it contributes to the increase of the amount of the yield.
- Positive, medium interaction was found between the length of the vegetation period and the average yield, thus in Mátra-region the varieties with longer vegetation period gave significantly higher yield in the average of the studied years, while the correlation analysis signed negative correlation between the length of the vegetation period and all the quality parameters.
- Positive significant correlation with different strength was found between the studied quality indexes. The strongest connection was appeared between the crude protein content and the wet gluten content.

- The slightest interaction was found between the Hagberg's fallen number and the other quality parameters, but also they could be listed into the strong category.
- It was proved in Mátra-region, that there was a negative correlation between the quality indexes and the average yield.

Based on the effect of meteorological parameters on the development, yield and quality of the wheat, the following conclusions can be made:

- There is a close positive correlation between the amount of the precipitation of the vegetation period and the plant height of the wheat. The strongest impact for the growth of the wheat plant is the amount of precipitation falling in March-April, while the average temperature of the vegetation period has a medium, negative connection with the plant height.
- The suitable development of wheat in Mátra-region is provided by the adequate amount of the spring precipitation, the not too cold temperature of winter and the lower early-summer temperature.
- In the region to the higher yields are provided with a mild winter temperature ensuring good wintering, large spring-early summer precipitation, promoted the tillering and stem elongation and the lower early summer temperature.
- The higher precipitation has a negative effect on the quality indicators, while the higher temperature of the vegetation period has positive effect on it.

The adaptability of the varieties was examined by Kang's stability analysis, based on it, in the early maturation group had the GK Öthalom, in the medium group Hunor, and in late maturity group Carlo had the best yield stability.

In the complex classification of the quality of the wheat varieties, it was found that the slightest difference between the varieties was in terms of the falling number and the highest difference was caused by the crude protein and gluten content, so these two indicators are mainly responsible for the changes of the Győri's Z-index in the Mátra-region. In the quality stability analysis conducted by Kang's stability analysis, Mv Palotás in the early maturity group, GK Petur in the medium maturity group and Mv Magdaléna in the late maturity group had the best stability value.

Due to the rapid change of varieties, a significant number of the varieties included in the experiment are no longer available in the National List of Varieties, so I make my suggestions carefully for the variety selection can be recommended for cultivation in the region. The Mv Palotás, Mv Dalma, Mv Emese, Ukrainka varieties from the early maturity group performed the best in the Mátra-region are

no longer in cultivation, only the GK Garaboly also given acceptable results is available for farmers. However, based on the results of the experiment, I would recommend to wheat producers in the region, if they are looking for a variety with a higher yield, good quality and reliable stability, varieties should be chosen from the early maturity group. I would not recommend Abony variety to the area's ecological conditions.

Mv Csárdás and GK Petur varieties, which have the best results from the medium maturity group in the experiment of Tass-puszta, are still included in the National List of Varieties, so they can be recommended for cultivation. If the producer is looking for variety for cultivation with high yield, I would recommend Buzogány, which is still in cultivation, but I do not recommend the choice of the Hunor variety. If the purpose of the grower is to reach a high yield crop with uniform quality, it is useful to choose variety from the medium maturity group in our region.

In the late maturity group none of the varieties included in our experiment had a high average yield, quality and good adaptability with it. Mv Magdaléna gave excellent quality next to average yield slightly below the average of the varieties, which has been kept by stability slightly below the average. The Maximus and Gaspard varieties were able to reach high yields, but their ability to adapt was also weak. If I had to choose among the varieties of the maturity group, I would recommend Mv Magdaléna, which has been still popular among farmers for many years.

Based on the evaluation of the data, it was confirmed, that the performance of the individual genotypes are various at the different production sites, the varieties can be produced the most successfully are different, so the varietal comparative experiments set up by the regions have raison d'etre to provide farmers with objective information for the variety selection.

I suggest to review and update the methodology of the winter wheat experiments, which would take into account the needs of the varieties instead of the uniform agrotechnology, as well as the participation of the varieties into the experiments for a longer period, carrying out the same tests in all experimental years and production sites, which is the basic criterion for the evaluation of the effect of the crop year.

During the analysis of meteorological data it would be reasonable to take into account the amount and the intensity of the daily precipitation instead of monthly data, considering the increased number of the large-precipitation phenomenons due to the effects of global climate change.

4.2. Examination of the fulfilment of the hypothesis in the light of the results

The results of the hypothesis based on the objectives are in the Table 5.

Table 5. Results of hypothesis analysis

Research hypothesis	Results of hypothesis analysis
H1: The examined agronomic features of the main wheat varieties have effect on the amount of the yield.	confirmed
H2: The examined agronomic features of the main wheat varieties have effect on the quality of the yield.	partly confirmed
H3: At Mátra-region the effect of the crop year influences the amount of the yield of winter wheat significantly.	confirmed
H4: At Mátra-region the effect of the crop year influences the quality of the yield of winter wheat significantly.	confirmed
H5: The best performed varieties at the Mátra-region can be chosen according to the results of the varietal comparative experiments.	confirmed
H6: Suggestible varieties for production in the different region of the country are different according to the results of the varietal comparative experiments.	partly confirmed

Source: Own editing

5. RELATED PUBLICATIONS

1. Journal articles

1.1. Revised journal article in Hungarian

BÉLTEKI I. – TÓTH SZ. ZS. – HOLLÓ S. – AMBRUS A. (2017): A csapadék mennyiségének és eloszlásának hatása a kukorica termésmennyiségére műtrágyázási tartamkísérletben. JOURNAL OF CENTRAL EUROPEAN GREEN INNOVATION. 5 (1) 13-29. p.

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FODOR L. – BÉLTEKI I. – SZEGEDI L. (2011): Nitrogen uptake and nitrogen content of winter wheat grown on heavy metal amended soil. Növénytermelés//Crop production, Vol. 60, 227-230. p.

BÉLTEKI I. –PETHES J. (2010): Effect of fertilization on yield of spring barley in different precipitation conditions. Növénytermelés// Crop production, Vol, 59, 369-372. p.

BÉLTEKI I. (2008): Adaptability of winter wheat (*Triticum aestivum L.*) varieties to soil and climatic conditions of Mátra Region. Cereal Research Communications. Vol. 36, 1007-1010. p.

2. Conference publications

2.1. In Hungarian language, complete

BÉLTEKI I. – FODOR L. – TÓTH SZ. ZS. – AMBRUS A. (2018): Komplex tápanyagutánpótlás hatásának vizsgálata a kukorica növekedésére és termésére. In: Dinya, László; Csernák, József (Szerk.) XVI. Nemzetközi Tudományos Napok, közlésre elfogadott

AMBRUS A. – BÉLTEKI I. – TÓTH SZ. (2018): A tápanyag-visszapótlási rendszerek összehasonlító vizsgálata az őszi búza hozamára. In: Dinya László; Csernák, József (Szerk.) XVI. Nemzetközi Tudományos Napok, közlésre elfogadott

TÓTH SZ. ZS. – LÁPOSI R. – AMBRUS A. – BÉLTEKI I. – KAPRINYÁK T. – FODOR L. (2018): A technológia fejlesztés lehetőségei a gabonatermesztésben a fenntartható gazdálkodás számára. In: Karsai Ildikó; Polgár Zsolt (Szerk.) XXIV. Növénynemesítési Tudományos Nap: Összefoglalók. Magyar Tudományos Akadémia, Budapest. 52. p.

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SZEGEDI L. – BÉLTEKI I. – PETHES J. (2012): A talaj és a növények kadmiumtartalmának összefüggés-vizsgálata nehézfémterheléses tartamkísérletben. In: Magda S. – Dinya L. (Szerk.) XIII. Nemzetközi Tudományos Napok. A tudományos napok előadásai és poszterei. CD, Gyöngyös, 2012. március 29-30.

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3. Book part

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