

Thesis of Doctoral (Ph.D.) Dissertation

**EFFECT OF THE CROP YEAR ON THE
AGRONOMICAL TRAITS OF WINTER WHEAT
VARIETIES**

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1. INTRODUCTION

As a result of the fast increase of the world population, cereals are becoming more and more important in human nutrition. Winter wheat is the most important cereal crop in the world and is produced on the highest acreage; its production site is 215-220 million ha.

The production area of winter wheat was increasing until the middle 1980s; the acreage reached 240 million ha from 200 million ha. After that some decrease in the acreage was observed, as wheat was substituted with other crops on those production sites where the production conditions were poor. This declining trend stopped in 1990. At that time wheat was produced on 215-220 million ha. Currently the wheat production site stabilized between 210-220 million ha.

The average yield of winter wheat has been growing since the 1960s. This increase was even more significant from the 1980s, when the average yield of winter wheat increased from 2.0 t ha⁻¹ to 3.0 t ha⁻¹ (intensive production development). Cereals have an important role in the national crop production system. Concerning the acreage and the role in human nutrition, winter wheat is of the highest importance and is a significant sector of the agricultural industry.

Quarter of Hungary's ploughland is used for winter wheat production, its production site ranges between 1.1-1.2 million ha, with 4.0-5.0 t average yields.

Except from a couple of years, the production site of winter wheat in Hungary exceeded 1.2 million ha from the beginning of 1970 to the end of 1980. As a result of the changed farm structure after the political change the production site of winter wheat significantly dropped. Today it is around 1.1 million ha.

The average yields increased from the 1960s to the end of the 1980s (from 2 t/ha to 5 t/ha) as a result of intensive fertilization. After that, due to the changes in the nutrition supplementation and farm structure, the average yields dropped to 3 t ha⁻¹ by the middle 1990s. In the last decade as a result of the more and more changeable weather significant changes in yields (3 t ha⁻¹ – 5 t ha⁻¹) are observed.

The importance of the wheat sector lies not only in its average yield and acreage, but in its production quality. The varieties with different genotypes can only realize their capacity under appropriate, variety- specific production technology. Winter wheat is one of our field crops with good adaptation capabilities and it can be produced everywhere in the country and suits well in our crop production system.

Hungary's favourable ecological capabilities allow of the production of special quality and quantity crops, which has to be considered in wheat production. Temperate climate is the

most favourable for winter wheat production, but due to its good adaptation capabilities it can be produced under different climates.

Crop production is affected by the different climatic and soil conditions, which can be significant influencing factors in wheat production as well. As a result, various cropping sites have formed in Hungary. Hungary's climate is suitable for wheat production, but there are good and less favourable cropping sites. Out of the climatic factors, winter wheat production is especially influenced by the temperature, the precipitation, and the soil type. These factors show great variance in the different cropping sites.

Usually, the productivity of the varieties depends on the vitality of the plant. The effect of the vitality on the yield lasts as long as the normal life conditions are assured. Beyond that, if these normal life conditions are missing, the adaptability of the variety has significant role in the formation of yield. The yield rank of varieties according to production sites is different. Currently the biggest issue our wheat production faces is the proper, production area specific variety selection. The problem is even more deepened by the extremely rich variety selection and the continuously changing crop years, making the profitability of the production unpredictable. Another problem is the change of market requirements, according to which today the primary objective of farmers is to produce the optimal amount with the best possible quality parameters. Contrary, in earlier years the increase of the product yield was emphasized in our wheat production.

2. THE PRECEDING OF THE WORK AND THE GOAL SET

In Hungary the production conditions are suitable for wheat production. The major wheat producing areas are in the Great Plain region. The counties of Békés and Csongrád, the Nagykovács and the Jászág regions have become the most important production sites in the last centuries, and it is not accidental that wheat breeding started here. The most important wheat production areas in the Transdanubian region are the Kisalföld, Baranya county and the Danube-valley, as well as the loess plains in the counties of Fejér and Tolna. The southern area of the Danube-Tisza Mid-Region i.e. Bács-Kiskun county is excellent for wheat production. The less wheat is produced on continuous sand soils (Nyírség, Kiskovács).

The geographic location of Hungary allows of the production of certain wheat varieties. The features of the varieties that have been developed under our circumstances are medium winter resistance, early maturity, drought resistance, good quality and sensitivity for short sunlight; therefore, they grow slowly in the spring. The important thing is that the variety should show its excellent characteristics - both in terms of quality and quantity – in the area where it is planned to be produced, i.e. it should have special adaptability. In order to reach this latter condition, professional breeding is required.

Today the trend is that the variety change has fastened and some wheat varieties cannot even spread after being bred, after 2-3 years of production they are withdrawn. Currently almost 120 varieties are available for farmers; most of them are home-bred. More than 80 % of the varieties are early or mid-season. As regards the quality of the wheat the extra food grade is dominant.

In winter wheat production the variety is the most effective, cheapest and most quickly returning investment, therefore, breeders have huge responsibility in producing suitable genetic materials for farmers. With suitable agrotechnical and weather conditions the yield of nearly all registered varieties reaches 5.0- 6.0 t ha⁻¹. Farmers usually look for the potentially higher yielding varieties. However, high yields are often incompatible with yield safety and excellent quality.

Recently several factors came up which modify the requirements put up for varieties. Out of these the more and more frequent extreme weather parameters is the most important, which make the profitability of wheat production unpredictable. The following factors modify the requirements towards varieties: applying the most up-to-date technology, the changing needs of consumers and mills, continuous improvement of the quality and the product yield.

Currently the wide range of varieties available in Hungary allow of selection, however, since farmers have to take several factors into account, the decision is difficult. Before choosing a

variety, the type of production site and the objective of production (quality or quantity oriented) have to be decided, and the right variety should be chosen by jointly considering these two factors.

My Ph.D dissertation includes the results of my research carried out in the University of Debrecen Centre for Agricultural Sciences Institute of Agricultural Research and Experiment Látókép Research Site between 2001-2005, with the supervision and professional guidance of Dr. Péter Pepó professor, head of institute. I try to recommend farmers on the correct variety selection and the improvement of production efficiency on the Hajdúság loess ridge.

The objectives of my research are as follows:

- to find at what rate the yield potential of different genotypes can be realized,
- analysing the yield stability and yield safety of winter wheat varieties of different maturity,
- analysing the quality parameters of winter wheat varieties of different maturity,
- analysing how quality is influenced by the genotype,
- analysing how yield safety and yield stability is influenced by the different crop years,
- to find the relation between the crop years and the quality parameters of winter wheat varieties,
- to verify the interaction between the genotype and the crop year on the quantity and quality of the yield by correlation and stability analysis,
- to learn more about the varieties in the agronomy point of view,
- to find the varieties with the best parameters in the Hajdúság region.

3. MATERIAL AND METHOD

3.1. The location, soil conditions and water management of the research site

Our experiment was carried out in the University of Debrecen Centre for Agricultural Sciences Institute of Agricultural Research and Experiment Látókép Research Site. The research site is situated on the Hajdúság loess ridge, 15 km from Debrecen, near the route 33. The soil of the research site is calcareous chernozem soil with a deep humus layer and clay loam texture, formed on loess. The soil was in good condition, categorized to loam according to the plasticity of Arany, the KA number is 43. The depth of the humus layer ranged between 80 and 90 cm, out of which the layer where the humus is equally distributed is 40-50 cm with 2.76% average humus content.

In the transition layer of the soil profile CaCO_3 is found in 75-100 cm depth. The soil particles are often covered by calcerous coat, and the lime content in this layer is 10-13 %.

The pH value (KCl) of the topsoil ranges between 6.3-6.5, the total N content ranges between 0.12 - 0.15 %. On the basis of the total nitrogen content the N-supply of the soil is moderate.

Based on the ammonium-lactate K_2O content results we found that the K supply of the soil of the research site (240 mg kg^{-1}) is good. After averaging the samples the phosphorus supply of the soil was medium-good (133 mg kg^{-1}).

The water management of the soil is good, as is characteristic for chernozem soils. According to Várallyai's classification it belongs to class IV. i.e. it has good water management and water holding capacity. The minimum water capacity of the soil (VKmin) in the 0-200 cm layer ranges between 33.65 - 46.00 w/v. In the same deep layer the unavailable water content (HV) ranges between 8.5 - 15.7 %. The soil water is in 8-10 m depth. The water holding capacity of the soil is good.

3.2. Evaluating the climate of the research years

In the 5 research years the extreme weather conditions can be well observed. Table 1 shows the most important weather parameters (precipitation, average temperature).

3.2.1. Evaluating the weather in the crop year of 2000/2001

As regards the precipitation of the crop year we found that it exceeded the 30 year average with 29.3 mm, resulted especially from the extra rain in the spring –early summer period (74.7 mm). In the autumn-winter period the precipitation was 45.4 mm less than the 30 year average. The mean temperature of the 2000/2001 crop year was 2.4 °C higher than the 30 year average. These mild temperature values were observed both in the autumn-winter and the spring-early summer periods.

3.2.2. Evaluating the weather in the crop year of 2001/2002

Compared to the 30 year average, significant rain deficit (216.3 mm) was observed in this crop year, which was similar both in the autumn-winter (109.7 mm) and in the spring-early summer (106.6 mm) periods. As regards the crop year as a total, the average temperature was similar to that of the 30 year average. The temperature in the autumn-winter period was 0.4 °C lower while in the spring-early summer period it was 0.5 °C higher than the average.

*Table 1: Evaluating the vegetation period of winter wheat
(Debrecen-Látókép, 2001-2005)*

2001	Growing season X-VI	Autumn-winter period X-II	Spring-early summer period III-VI
precipitation (mm)	430,2	141,3	288,9
devation from the 30 year average (mm)	29,3	-45,4	74,7
temperature (°C)	9,3	5,5	14
devation from the 30 year average (°C)	2,4	3,1	1,4
2002	Growing season X-VI	Autumn-winter period X-II	Spring-early summer period III-VI
precipitation (mm)	184,6	77	107,6
devation from the 30 year average (mm)	-216,3	-109,7	-106,6
temperature (°C)	6,9	2	13,1
devation from the 30 year average (°C)	0	-0,4	0,5
2003	Growing season X-VI	Autumn-winter period X-II	Spring-early summer period III-VI
precipitation (mm)	279,6	179,6	100
devation from the 30 year average (mm)	-121,3	-7,1	-114,2
temperature (°C)	6,3	0,8	13,1
devation from the 30 year average (°C)	-0,6	-1,6	0,5
2004	Growing season X-VI	Autumn-winter period X-II	Spring-early summer period III-VI
precipitation (mm)	376,5	211,3	165,2
devation from the 30 year average (mm)	-24,4	24,6	-49
temperature (°C)	6,6	1,9	12,6
devation from the 30 year average (°C)	-0,3	-0,5	0
2005	Growing season X-VI	Autumn-winter period X-II	Spring-early summer period III-VI
precipitation (mm)	410,4	194,9	215,5
devation from the 30 year average (mm)	9,5	8,2	1,3
temperature (°C)	6,7	2,5	11,9
devation from the 30 year average (°C)	-0,2	0,1	-0,7

3.2.3. Evaluating the weather in the crop year of 2002/2003

Compared to the 30 year average, we found that similarly to the previous year this crop year was draughty as well. The precipitation deficit was 121.3 mm compared to the 30 year average, caused especially by the deficit of the spring-early summer period (114.2 mm).

Compared to the 30 year average, the mean temperature was 0.6 °C lower in the growing season and 1.6 °C lower in the autumn-winter period. The mean temperature in the spring-early summer period was 0.5 °C higher than the average, similarly to the previous year. The unfavourable effect of the warm spring weather was made worse by the draught in the previous year, which could not be mitigated by decreased water supply of the chernozem soil, i.e. we can state that 2002/2003 was a clearly unfavourable draughty crop year.

3.2.4. Evaluating the weather in the crop year of 2003/2004

The precipitation of the cropping year (376.5) was satisfactory for wheat production. After the favourable autumn-winter precipitation (211.3 mm) the amount was somewhat lower (49.0 mm) in the spring-early summer period (162.5 mm), compared to the 30 year average.

With slight difference (-0.3 °C), the mean temperature values were similar to the 30 year average, as well as the values in the autumn-winter and in the spring-early summer periods.

3.2.5. Evaluating the weather in the crop years of 2004/2005

The precipitation in the crop year of 2003/2004 (410.4 mm) was optimal for winter wheat. The values were similar to the 30 year average, and the distribution was nearly equal in the autumn-winter (194.9 mm) and in the spring-early summer periods (215.5 mm).

As regards the mean temperature values, they were average and ranged around the 30 year average in the crop year (6.7 °C), in the autumn-winter (2.5 °C) and in the spring-early summer periods (11.9 °C).

3.3. The agrotechniques applied in the research

In the University of Debrecen Centre for Agricultural Sciences Institute of Agricultural Research and Experiment Látókép Research Site the experiment was carried out under unique agrotechnical conditions on small plots. The experiment was carried out in random blocks in four repetitions each year. The plot size was unique each year (1.65 x 9.20 m = 15.18 m²). The yield potential and the quality parameters (valorigraph value, wet gluten content, gluten deformation, Hagberg's falling number) of wheat varieties of different maturity have been analysed between 2001-2005. Wintersteiger plot sowing machine and Sampo plot harvester was used each year.

3.4. The winter wheat varieties examined in the research

During the 5 research years several winter wheat varieties of early (59), mid-season (47) or late (31) maturity groups have been examined. However, in order to be able to compare the values, my thesis includes and evaluates only those varieties in each maturity group which have been examined in all 5 research years.

The following varieties were used in the research:

early maturing varieties: GK Öthalom, Alföld 90, Kompolti 3, GK Élet, GK Kalász, GK Garaboly, Flori 2, GK Verecke, Abony, Mv Dalma, Mv Palotás, Mv Emese, Ukrainka, Rusija

Mid-season varieties: GK Marcal, Mv Magvas, GK Cipó, Róna, Hunor, Buzogány, GK Miska, Mv Csárdás, GK Petur, GK Rába, MF Kazal

Late varieties: Gaspard, Mv Magdaléna, Maximus, Ludwig, Carlo, Capo.

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

The product yield and the wet content of the wheat varieties have been measured at and after harvesting in four repetitions. Later the wet content was standardized to 14 %.

The baking quality experiments have been carried out in the accredited Central Laboratory headed by Dr. Zoltán Győri.

The wet gluten content and the gluten deformation was determined according to the MSZ-ISO-5531:1993 standard by LABOR-MIM and Glutomatic 2200 gluten washing instrument and 2015 centrifuge, the valorigraph value was determined according to the MSZ-ISO-5530-3:1994, and MSZ-ISO-5530-3:1995 standard by LABOR-MIM valorigraph and Brabender farinograph, while Hagberg's falling number was determined according to the MSZ-ISO-3093:1995 standard by Perten falling number system. IBM compatible computer with Windows XP operation system was used for the recording, processing and evaluation of the data. The used spreadsheet and statistical software: Microsoft Excel 2003, SPSS 13.0 for Windows.

The statistical evaluation of the data was carried out by variance analysis, Kang's stability analysis and Pearson's correlation analysis.

4 RESULTS AND DISCUSSION

4.1. Factors influencing the variety composition of winter wheat

When examining the variety characteristics, one of the measures of value was the yield potential and yield stability of the varieties, which is influenced to smaller or greater extent by environmental factors (climate, soil) and by agrotechnical conditions (nutrient supply, crop rotation, crop protection). Even on chernozem soils with good water and nutrient management, the crop yield of winter wheat is primarily influenced by water supply and secondly by temperature.

Unfortunately, as a result of the climate change in Hungary, especially in the Great Plain region the number of dry crop years and the weather anomalies has been increasing. The increase of the draughty trend is not alleviated by humid periods.

4.2. Factors influencing the grain production in winter wheat

The crop years has a strong influence on the formation of the yield of winter wheat. Even if favourable soil and agrotechnical circumstances are provided, the crop year significantly influences the yield of the varieties in different maturity groups.

4.2.1. Complex evaluation of the yields in different crop years

Comparing the average yields of the different maturity groups (Table 2) in the 5 research years we found that the mid-season maturity group had the highest crop yields (6383 kg ha^{-1}). The lowest yields (5878 kg ha^{-1}) were realized in the late maturity group. If the average yields of the maturity groups are separately evaluated, we find that except from the growing season of 2001/2002 (when the highest yield (5546 kg ha^{-1}) was realized in the early maturity group) similarly to the upper mentioned, the mid-season maturity group had the highest yield. The lowest yields were observed in the late maturity group, except from the crop year of 2002/2003.

The difference between the crop years are well represented by the average yields of the maturity groups. The highest yield (8335 kg ha^{-1}) was realized in the crop year of 2003/2004, while the lowest (3210 kg ha^{-1}) was realized in the crop year of 2002/2003. The most favourable crop year for wheat production was 2003/2004. At that time, highest yields were realized in each maturity group (average yield of the early maturity group: 8348 kg ha^{-1} , average yield of the mid-season maturity group: 8826 kg ha^{-1} , average yield of the late maturity group: 7831 kg ha^{-1}). The lowest yields were observed in the extremely draughty crop year of 2002/2003 (average yield of the early maturity group: 2844 kg ha^{-1} , average yield of the mid-season maturity group: 3421 kg ha^{-1} , average yield of the late maturity group: 3364

kg ha⁻¹). That year the harmful effects on winter wheat yields could not have been mitigated even on good-quality chernozem soils.

Table 2: The crop yield of winter wheat varieties of different maturity groups broken down to crop years
(average of the varieties)
(Debrecen-Látókép, 2001-2005)

Year	Grain yield kg ha ⁻¹			
	Early maturing	Mid-season	Late	Average
2001	6841	7263	6754	6953
2002	5546	5421	5315	5427
2003	2844	3421	3364	3210
2004	8348	8826	7831	8335
2005	6668	6983	6631	6761
Average	6049	6383	5979	6137
SD _{5%} averaging the years between the varieties	713	888	835	-
SD _{5%} averaging the varieties between the years	195	275	353	-
SD _{5%} between any two combinations	731	913	865	-

4.2.2. The effect of the crop year on the yields of the different varieties

We have analysed the yields one by one broken down to varieties according to maturity groups. We compared the yields of winter wheat varieties of different maturity groups and the relative yield of the average of the variety group. *Tables 3, 4, and 5* show the absolute and relative yields of wheat varieties of different maturity groups.

2000/2001 crop year

The data reveal that the crop year of 2000/2001 was favourable for the yield formation of winter wheat. Compared to the average yield of the variety groups, the most favourable relative yields were obtained in the mid-season maturity group, i.e. the difference between the highest (GK Rába 110.9%) and the lowest (Hunor 91.9 %) yielding variety was 19.0%. This value was 34.3 % within the late maturity group. The highest production level was reached by Gaspard (114.2 %), the lowest was of Maximus (79.9%).

Out of the examined varieties, in the early maturity group Ukrainka (7691 kg ha⁻¹), GK Garaboly (7553 kg ha⁻¹) and GK Öthalom (7316 kg ha⁻¹), in the mid-season maturity group GK Rába (8059 kg ha⁻¹) and GK Marcal (7857 kg ha⁻¹), in the late maturity group Gaspard (7712 kg ha⁻¹) and Ludwig (7551 kg ha⁻¹) had the highest yield. The lowest yielding varieties were GK Élet (5790 kg ha⁻¹) and Alföld 90 (6032 kg ha⁻¹) in the early maturity group, Hunor

(6679 kg ha⁻¹), Róna (6697 kg ha⁻¹) and GK Miska (6746 kg ha⁻¹) in the mid-season maturity group, and Maximus (5395 kg ha⁻¹) in the late maturity group.

2001/2002 crop year

In the 2001/2002 crop year, the unfavourable weather conditions were reflected by the yields as well. Contrary to that, the unfavourable conditions were moderated by the good quality calcareous chernozem soil, thus the yield quantities were better than the average. The highest difference (39.3%) between the relative yields of the varieties was found in the mid-season maturity group (between GK Cipó 113.5% and MF Kazal 74.2%). In the late maturity group Maximus (113.5%) exceeded the average by highest. Compared to the average of the maturity group, Capo had the highest negative difference (84.2%). The smallest differences among the varieties were found in the early maturity group. As regards the relative yields, the difference between the best (GK Kalász 115.1%) and worst (GK Élet 89.6%) yielding varieties was 25.5%. In the early maturity group the best average yields were obtained by GK Kalász (6385 kg ha⁻¹) and Abony (6288 kg ha⁻¹). In the mid-season maturity group GK Cipó (6155 kg ha⁻¹) and Róna (6034 kg ha⁻¹), in the late maturity group Maximus (6033 kg ha⁻¹) had the highest yield. The unfavourable crop years were least tolerated by GK Élet (4970 kg ha⁻¹), GK Öthalom (5083 kg ha⁻¹), Kompolti 3 (5106 kg ha⁻¹) and Mv Emese (5120 kg ha⁻¹) in the early maturity group, MF Kazal (4021 kg ha⁻¹) in the mid-season maturity group, and Capo (4473 kg ha⁻¹) and Mv Magdaléna (4712 kg ha⁻¹) in the late maturity group.

2002/2003 crop year

The lowest yields of the winter wheat varieties were observed in 2003. The unfavourable crop year considerably contributed to the great differences among the early maturing varieties regarding the relative yields. The difference between the best (Mv Palotás 128.4%) and worst (GK Garaboly 82.2%) yielding varieties was 46.2%. In the mid-season maturity group the relative yield values ranged between 83.4% (GK Petur) and 108.7% (GK Marcal). The yield values were most unique within the late maturity group. Here the difference between the varieties was only 14.4% (between Ludwig 108.4% and Carlo 94.0%).

Each variety in the maturity group responded with lower yields to ecological stress. Compared to other varieties, the following varieties had better results: Mv Palotás (3651 kg ha⁻¹) and Mv Emese (3514 kg ha⁻¹) in the early maturity group, GK Marcal (3718 kg ha⁻¹) and Róna (3622 kg ha⁻¹) in the mid-season maturity group, and Ludwig (3646 kg ha⁻¹) in the late maturity group. Due to the draught, the weakest yields were realized by GK Garaboly (2338

kg ha⁻¹) in the early maturity group , GK Petur (2855 kg ha⁻¹) and Mv Csárdás (2970 kg ha⁻¹) in the mid-season maturity group, and Carlo (3162 kg ha⁻¹) in the late maturity group.

2003/2004 crop year

The highest yields were realized in the crop year of 2003/2004. Thanks to the favourable climatic conditions smaller differences were found between the relative yields of the varieties. The difference between the yields of the best (Flori 2 111,8%) and weakest (Mv Palotás 92,0%) varieties was 19.8 % compared to the average yield of the variety group. The best relative yields were observed in the mid-season maturity group, since the difference between the highest (MF Kazal 105.9%) and lowest (Hunor 86.4%) yielding varieties was 19.0%. Within the groups of late varieties, the variety with the highest relative yield was Maximus (110.1%), and with the lowest relative yield was Capo (89.0%).

The favourable climate conditions resulted in excellent yields. Except from some varieties, the average yield values exceeded 8.0 t ha⁻¹ irrespectively of the maturity group. In the early maturity group the following varieties had the most excellent yields: Flori 2 (9336 kg ha⁻¹), GK Garaboly (9053 kg ha⁻¹). Mv Palotás (7682 kg ha⁻¹), Rusija (7710 kg ha⁻¹), Alföld 90 (7770 kg ha⁻¹) and GK Élet (7902 kg ha⁻¹) had lower yields than the average of the group. In the mid-season maturity group MF Kazal (9343 kg ha⁻¹), Róna (9299 kg ha⁻¹), GK Marcal (9230 kg ha⁻¹), Buzogány (9226 kg ha⁻¹) and GK Rába (9221 kg ha⁻¹) had the best yields. In this maturity group only the yield of Hunor (7622 kg ha⁻¹) was below 8.0 t ha⁻¹. In the late maturity group Maximus (8620 kg ha⁻¹) had the highest average yield. Capo (6971 kg ha⁻¹) was the lowest yielding variety.

2004/2005 crop year

Similarly to the previous crop year, the weather of the crop year of 2004/2005 was also favourable for the yield formation of winter wheat. As regards the relative yield levels, the greatest differences (36.5%) among the varieties was found in the mid-season maturity group (between Buzogány 119.6% and Hunor 83.1%). In the early maturity group the relative yields ranged between 116.8% (Flori 2) and 91.7% (Abony). The smallest difference (16.4%) among the varieties was measured in the late maturity group (between Gaspard 106.0% and Capo 89.6%).

As regards the average yields, Flori 2 (7789 kg ha⁻¹), GK Garaboly (7596 kg ha⁻¹), Ukrainka (7190 kg ha⁻¹) had higher than average values in the early maturity group. Within the three maturity groups, the mid-season Buzogány (8354 kg ha⁻¹) had the highest average yield. In the late maturity group the yield of Gaspard (7030 kg ha⁻¹) exceeded 7,0 t ha⁻¹-t. In the crop

year of 2004/2005 in the early maturity group Mv Palotás (6199 kg ha⁻¹), Alföld 90 (6144 kg ha⁻¹) and Abony (6116 kg ha⁻¹) seemed low yielding varieties. In the mid-season maturity group Hunor (5804 kg ha⁻¹) while in the late maturity group Capo (5940 kg ha⁻¹) had the lowest yields.

4.2.3. Kang's stability analysis of winter wheat varieties

In order to analyse the yield stability of winter wheat varieties stability analysis was used, during which the interaction between the environment (crop year) and the different genotypes was revealed. The 5-year period seems a little short for carrying out the stability analysis; however, the crop years were quite different, resulting in the fact that the fitting of the lines are extremely good. This is confirmed by the high R values (0.9142-0.9927) except from the late variety of Maximus (0.8015), therefore the yield stability could have been accurately evaluated. It is proved that the yield stability of those varieties is best, of which the regression coefficient is smallest. Out of the varieties of different maturity groups, we regarded the yield stability of a certain genotype favourable if the regression coefficient was under 0.9000. Based on the linear regression coefficients the varieties with the best yield stability in the examined five years were the following:

Early maturity group: Mv Palotás (0.7370, average yield: 6023 kg ha⁻¹), Mv Emese (0.8371, average yield : 5945 kg ha⁻¹), Alföld 90 (0.8779, average yield: 5677 kg ha⁻¹)

Mid-season maturity group: Hunor (0.7314, average yield: 5833 kg ha⁻¹)

Late maturity group: Capo (0.8437, average yield: 5448 kg ha⁻¹)

On the average of the five research years, the yield stability of the varieties with high yield potential was usually lower and their response for environmental changes was stronger. The best situation is if the high crop yield and the high yield stability go together. In our research it was true only for the early maturing variety of Mv Palotás.

Table 3: The absolute and relative yields of the early maturing winter wheat varieties in different crop years (Debrecen-Látókép, 2001-2005)

Variety	Yield											
	2001		2002		2003		2004		2005		2001-2005 average	
	kg ha ⁻¹	%	kg ha ⁻¹	%	kg ha ⁻¹	%	kg ha ⁻¹	%	kg ha ⁻¹	%	kg ha ⁻¹	%
GK Öthalom	7316	106,9	5083	91,7	2673	94,0	8235	98,6	6323	94,8	5926	98,0
Alföld 90	6032	88,2	5695	102,7	2745	96,5	7770	93,1	6144	92,1	5677	93,9
Kompolti 3	6281	91,8	5106	92,1	2480	87,2	8759	104,9	6502	97,5	5826	96,3
GK Élet	5790	84,6	4970	89,6	2527	88,9	7902	94,7	6829	102,4	5604	92,6
GK Kalász	6994	102,2	6385	115,1	2403	84,5	8601	103,0	6533	98,0	6183	102,2
GK Garaboly	7553	110,4	5801	104,6	2338	82,2	9053	108,4	7596	113,9	6468	106,9
Flori 2	6821	99,7	5565	100,3	2762	97,1	9336	111,8	7789	116,8	6454	106,7
GK Verecke	7216	105,5	5537	99,9	2957	104,0	8489	101,7	6384	95,7	6117	101,1
Abony	6559	95,9	6288	113,4	2946	103,6	8543	102,3	6116	91,7	6090	100,7
Mv Dalma	7095	103,7	5356	96,6	3043	107,0	8557	102,5	6758	101,3	6162	101,9
Mv Palotás	6908	101,0	5675	102,3	3651	128,4	7682	92,0	6199	93,0	6023	99,6
Mv Emese	6276	91,7	5120	92,3	3514	123,6	8208	98,3	6607	99,1	5945	98,3
Ukrainka	7691	112,4	5588	100,8	3197	112,4	8033	96,2	7190	107,8	6340	104,8
Rusija	7238	105,8	5468	98,6	2576	90,6	7710	92,4	6382	95,7	5875	97,1
Average	6841	100	5546	100	2844	100	8348	100	6668	100	6049	100
SD_{5%} variety	459	6,7	819	14,8	650	22,9	631	7,6	1008	15,1	-	-

Table 4: The absolute and relative yields of mid-season winter wheat varieties in different crop years
(Debrecen-Látókép, 2001-2005)

Variety	Yield											
	2001		2002		2003		2004		2005		2001-2005 average	
	kg ha ⁻¹	%	kg ha ⁻¹	%	kg ha ⁻¹	%	kg ha ⁻¹	%	kg ha ⁻¹	%	kg ha ⁻¹	%
GK Marcal	7857	108,2	5202	95,9	3718	108,7	9230	104,6	7314	104,8	6664	104,4
Mv Magvas	7355	101,3	5572	102,8	3449	100,8	8896	100,8	6619	94,8	6378	99,9
GK Cipó	7510	103,4	6155	113,5	3483	101,8	8853	100,3	7295	104,5	6659	104,3
Róna	6697	92,2	6034	111,3	3622	105,8	9299	105,4	7316	104,8	6593	103,3
Hunor	6679	91,9	5568	102,7	3492	102,1	7622	86,4	5804	83,1	5833	91,4
Buzogány	7363	101,4	5456	100,6	3590	104,9	9226	104,5	8354	119,6	6798	106,5
GK Miska	6746	92,9	5378	99,2	3295	96,3	8924	101,1	6822	97,7	6233	97,7
Mv Csárdás	7037	96,9	5633	103,9	2970	86,8	8088	91,6	6459	92,5	6037	94,6
GK Petur	7557	104,0	4880	90,0	2855	83,4	8379	94,9	7209	103,2	6176	96,8
GK Rába	8059	110,9	5735	105,8	3591	104,9	9221	104,5	7035	100,7	6728	105,4
MF Kazal	7039	96,9	4021	74,2	3572	104,4	9343	105,9	6582	94,3	6111	95,7
Average	7263	100	5421	100	3421	100	8826	100	6983	100	6383	100
SD_{5%} variety	374	5,5	1104	20,8	1168	34,7	753	9,6	812	374	-	-

Table 5: The absolute and relative yield of the late winter wheat varieties in different crop years
(Debrecen-Látókép, 2001-2005)

Variety	Yield											
	2001		2002		2003		2004		2005		2001-2005 average	
	kg ha ⁻¹	%	kg ha ⁻¹	%	kg ha ⁻¹	%	kg ha ⁻¹	%	kg ha ⁻¹	%	kg ha ⁻¹	%
Gaspard	7712	114,2	5486	103,2	3291	97,8	8024	102,5	7030	106,0	6309	105,5
Mv Magdaléna	6656	98,5	4712	88,7	3367	100,1	8291	105,9	6801	102,6	5966	99,8
Maximus	5395	79,9	6033	113,5	3310	98,4	8620	110,1	6925	104,4	6057	101,3
Ludwig	7551	111,8	5548	104,4	3646	108,4	7567	96,6	6589	99,4	6180	103,4
Carlo	6764	100,1	5636	106,0	3162	94,0	7511	95,9	6503	98,1	5915	98,9
Capo	6447	95,5	4473	84,2	3407	101,3	6971	89,0	5940	89,6	5448	91,1
Average	6754	100	5315	100	3364	100	7831	100	6631	100	5979	100
SD_{5%} variety	374	5,5	1104	20,8	1168	34,7	753	9,6	812	374	5,5	-

4.2.4. Analysis of the interaction between yields and meteorological parameters with Pearson's correlation

Besides the genetics of the variety, the yields of winter wheat varieties are directly and indirectly influenced by agrotechnical factors as well. These factors have positive or negative effect on the magnitude of the given parameters. Out of the statistical methods, Pearson's correlation gives numerical determination of the strength and direction of the interaction between the influencing factors. According to winter wheat maturity groups, we have analysed the interaction between the yield and the meteorological parameters (precipitation, temperature) by using a correlation coefficient (r). In order to improve the accuracy of the method, the typical meteorological data (precipitation, temperature) was broken down into autumn-winter (October, November, December, January, February), spring (March, April) and early summer (May, June) periods.

Analysing the relation between the meteorological parameters and the yield in the different maturity groups, we found that except from the early summer temperature each meteorological parameter had a positive impact on the product yield, simply the strength of the correlation was different. The precipitation of the growing season was in strong correlation with the product yield of the varieties (early maturity group: 0.527**, mid-season maturity group: 0.591**, late maturity group: 0.571**). The correlation between the product yield and the spring precipitation was quite strong in each maturity group (early maturity group: 0.703**, mid-season maturity group: 0.722**, late maturity group: 0.715**), which shows that sufficient water supply enhances tillering and organic material production.

The average temperature in the spring had close positive effect on the product yield (early maturity group: 0.553**, mid-season maturity group: 0.524**, late maturity group: 0.519**). There was quite close negative correlation between the average temperature in early summer and the product yield in each maturity group (early maturity group: -0.885**, mid-season maturity group: -0.838**, late maturity group: -0.840**). It reflects the strong unfavourable effect of weather anomalies in the period of intensive vegetative growth and grain filling.

4.2.5. The water use of winter wheat varieties in different crop years

Using the yield per amount of precipitation in the crop year, we analysed the water utilization of the varieties of different maturity groups on the average of the varieties year by year.

Considering the yield results per 1 mm precipitation in a given crop year we found that the water utilization of the varieties of different maturity groups was as follows: in 2000/2001 between

15.70 kg and 16.88 kg, in 2001/2002 between 28.79 kg and 30.04 kg, in 2002/2003 due to severe draught below 13.00 kg, in the favourable crop year of 2003/2004 around or above 20.00 kg, while in 2004/2005 – similar to the crop year of 2000/2001- between 16.00 and 17.00 kg.

On the average of five years, the following hybrids had the best water utilization: in the early maturity group GK Garaboly (19.98 kg), Flori 2 (19.93 kg), Ukrainka (19.69 kg) and GK Kalász (19.64 kg), in the mid-late maturity group GK Cipó (20.91 kg), Buzogány (20.87 kg), GK Rába (20.85 kg) and Róna (20.75 kg), in the late maturity group Gaspard (19.57 kg).

As a general rule, no significant difference was found among the water utilization of the genotypes of different maturity groups. The results confirmed that the water utilization of winter wheat varieties is determined by the water supply in the crop year.

4.3. Evaluation of the quality parameters of winter wheat

The quality parameters of winter wheat varieties depend on several factors. Some of them are genetically coded and are typical for the given variety. Thus, high importance should be given to the correct variety selection. However, the prevailing of the genetically coded maximum values are influenced (usually are decreased) by agroecological factors, such as the crop year and the applied agrotechniques.

4.3.1. Combined evaluation of the quality parameters of the crop years

Averaging the varieties we have compared the valorigraphic value, wet gluten content, gluten deformation and Hagberg's falling number in different maturity groups (*Table 6*).

As regards the valorigraph number, considering the average of the five years we found that it was highest (50.2) in the early maturity group. The lowest value was observed in the late maturity group (45.9). As regards the valorigraph number, all three maturity groups were classified to food-grade quality, namely B2. Separately evaluating the valorigraph number of the crop years the significant differences between the crop years are well represented. Considering the valorigraph value of the certain crop years on the average of the variety groups, we found that the severe draught in 2003 had a negative effect on this parameter as well, as the wheat yields were classified only in the weakest (C₂) feed grade according to the measured value (26.3). Similarly, the crop year of 2001/2002 was weak. The crop year of 2004/2005 turned out to be the best, when the valorigraph value was 72.4, thus the yield quality was qualified extra food grade.

Evaluating the wet gluten content of the maturity groups averaging the crop years we found that the most favourable gluten % (36.35 %) was observed in the late maturity groups qualifying for

extra food grade, just as the early maturing genotypes (34.78 %). The varieties in the mid-season maturity groups belonged to a slightly lower (32.27 %) but still food grade I. Comparing the wet gluten content of the given crop years averaging the maturity groups we found that, contrary to the severe drought by far the highest gluten content (45.07%) was observed in the crop year of 2002/2003, parallel with a very weak (26.3) valorigraph value. The lowest gluten content was measured in the crop year of 2001/2002, when the gluten % was only 26.65 % which represents a very weak gluten quality. The wet gluten content of the other years was average, and qualified the winter wheat varieties for food grade I.

We compared the gluten deformation of the winter wheat varieties in different maturity groups. The table shows that averaging the crop years, on the basis of the average gluten deformation none of the maturity groups was classified in the extra quality class. The most favourable value (5.8 mm) was reached by the varieties in the mid-season maturity group, and it shows that averaging the varieties the maturity group qualifies extra food grade. The gluten deformation of the late maturity group was higher (8.3 mm). In this case higher gluten content (36.35 %) was accompanied by better gluten deformation value. The average gluten deformation of the early maturing varieties was also higher (6.5 mm), thus this maturity group qualifies extra food grade as well. The relatively high average gluten deformation values were resulted from the extremely unfavourable and draughty crop year of 2002/2003.

If we compare the gluten deformation mean values of a certain crop year on the average of the maturity groups, the crop year of 2002/2003 is excelled with its extremely unfavourable weather, representing by very weak (19.5 mm) gluten deformation index. The gluten deformation values are favourable in other crop years, qualifying the wheat varieties in the extra and food grade I class. The best gluten deformation (2.5 mm) was observed in 2001/2002, however this value was accompanied by lower wet gluten content and valorigraph value.

We have analysed Hagberg's falling number in different maturity groups on the average of the crop years. The table shows that in each of the three maturity groups the falling number exceeds 300 sec, qualifying the varieties in extra food grade class. These values are 353, 353 and 334 sec in the mid-season, late and early maturity groups, respectively. If the different crop years are individually analysed on the average of the maturity groups, we find that the falling numbers qualify the maturity groups in the extra food grade class. The lowest Hagberg's number (299 sec)

was measured in the crop year of 2001/2002, while the highest (410) was measured in 2002/2003.

Table 6: The valorigraph value, wet gluten content, gluten deformation and Hagberg's falling number of winter wheat varieties of different maturity groups (average of the varieties) (Debrecen-Látókép, 2001-2005)

Year	Valorigraph value			
	Early maturing	Mid-season	Late	Average
2001	45,2	45,1	46,5	45,6
2002	40,4	39,8	36,2	38,8
2003	29,7	27,5	21,7	26,3
2004	62,4	53,8	52,8	56,3
2005	73,3	71,5	72,5	72,4
Average	50,2	47,5	45,9	47,9
SD_{5%} years	28,8	24,9	30,7	-
Years	Wet gluten content (%)			
	Early maturing	Mid-season	Late	Average
2001	30,29	27,77	32,69	30,25
2002	27,67	26,93	25,34	26,65
2003	46,45	40,09	48,66	45,07
2004	31,73	30,78	36,70	33,07
2005	37,77	35,76	38,38	37,30
Average	34,78	32,27	36,35	34,47
SD_{5%} years	14,65	9,78	16,71	-
Year	Gluten deformation (mm)			
	Early maturing	Mid-season	Late	Average
2001	3,7	3,0	3,2	3,3
2002	2,1	2,5	2,9	2,5
2003	18,8	16,1	23,6	19,5
2004	3,3	3,1	6,9	4,4
2005	4,5	4,1	4,7	4,4
Average	6,5	5,8	8,3	6,8
SD_{5%} years	9,3	8,0	12,6	-
Year	Hagberg's falling number (sec)			
	Early maturing	Mid-season	Late	Average
2001	307	334	342	328
2002	301	283	314	299
2003	413	417	399	410
2004	330	358	365	351
2005	317	375	346	346
Average	334	353	353	347
SD_{5%} years	130	100	133	-

4.3.2. The analysis of the quality stabilization of winter wheat varieties by Kang's stability analysis

Similarly to the yield stability analysis of winter wheat varieties of different maturity groups, we used stability analysis in order to statistically analyse the stability of the quality parameters (valorigraph value, wet gluten content, gluten deformation, Hagberg's falling number). On the basis of linear regression lines the quality stability of winter wheat varieties are difficult to evaluate, as the R^2 values in the equation are extremely varied (valorigraph value: 0.5141-0.9914, wet gluten content: 0.3560-0.9954, gluten deformation: 0.4120-0.9981, Hagberg's falling number: 0.0259-0.9960), and they determine the fitting of the lines. The low R^2 values and thus the unfavourable fitting of the graphs are resulted from the fact that in case of some varieties we did not have measuring data for the different quality parameters in the 2001/2002 crop year. For each quality parameter, the varieties in our research are considered as having favourable yield stability under 0.8000 regression coefficient value. On the basis of the linear regression coefficient, analysing the 5 examined years according to the quality parameters we found that the varieties with the best yield stability are as follows:

Valorigraph value

Early maturity group: GK Öthalom (0.6806, average valorigraph value: 56.9), GK Garaboly (0.6966, average valorigraph value: 48.4), Rusija (0.7955, average valorigraph value: 48.4)

Mid- season maturity group: Buzogány (0.6245, average valorigraph value: 43.6), MF Kazal (0.7816, average valorigraph value: 45.8), Hunor (0.7923, average valorigraph value: 52.5)

Late maturity group: Gaspard (0.7989, average valorigraph value: 41.4)

Wet gluten content

Early maturity group: Ukrainka (0.5008, average wet gluten %: 32.79%), GK Öthalom (0.7613, average wet gluten: 34.89%)

Mid- season maturity group: Hunor (0.4976, average wet gluten: 30.60%), GK Petur (0.6380, average wet gluten: 33.76%)

Late maturity group: Maximus (0.7896, average wet gluten: 36.28%)

Gluten deformation

Early maturity group: Alföld 90 (0.6412, average gluten deformation: 6.0 mm), Mv Emese (0.6469, average gluten deformation: 4.8 mm), Ukrainka (0.6471, average gluten deformation: 5.4 mm), GK Öthalom (0.6570, average gluten deformation: 5.4 mm)

Mid- season maturity group: GK Petur (0.2960, average gluten deformation: 4.5 mm), Hunor (0.7037, average gluten deformation 4.9 mm), GK Rába (0.7117, average gluten deformation: 5.8 mm), GK Cipó (0.7443, average gluten deformation: 4.8 mm), MF Kazal (0.7616, average gluten deformation: 4.8 mm)

Late maturity group: Gaspard (0.6461, average gluten deformation: 8.4 mm)

Hagberg's falling number

Early maturity group GK Verecke (0.1831, average falling number: 382.9 sec), Rusija (0.2937, average falling number: 279.4 sec), Mv Palotás (0.6059, average falling number: 363.3 sec), Ukrainka (0.7830, average falling number: 368.3 sec), Mv Emese (0.7976, average falling number: 316.4 sec)

Mid- season maturity group: GK Cipó (0.0488, average falling number: 361.8 sec), Mv Magvas (0.5567, average falling number: 407.1 sec), Hunor (0.7086, average falling number: 389.0 sec)

Late maturity group: Ludwig (0.4281, average falling number: 367.6 sec), Capo (0.5284, average falling number: 353.9 sec)

On the basis of our results we can claim that on average of five years the following varieties had relatively high valorigraph values and high stability: the early maturing variety of GK Öthalom, the mid-season Hunor. Excellent wet gluten % and good stability was measured in the case of the early maturing GK Öthalom, the mid-season GK Petur, and the late Maximus. The following varieties had acceptable gluten formation and yield stability: the early maturing variety of Mv Emese, GK Öthalom and Ukrainka, as well as the mid-season GK Petur, GK Cipó, MF Kazal and Hunor. The change in the agroecological factors had no unfavourable effect on Hagberg's falling number. Excellent falling number and good stability was observed in the case of the following varieties: the early maturing variety of GK Verecke, Ukrainka and Mv Palotás, the mid-season Hunor and GK Cipó, and the late Ludwig. All in all we found that the early variety of GK Öthalom and the late Hunor had at least three good results out of the four examined parameters on average of five years.

4.3.3. The analysis of the interaction between the quality parameters and the meteorological parameters by Pearson's correlation

Similarly to the crop yields, we used Pearson's correlation within the maturity groups for each variety to find the relation between the valorigraph value, wet gluten content, gluten deformation, Hagberg's falling number, and the various climatic (precipitation, temperature) parameters, as well as the relation between certain quality parameters. In this case the meteorological data (precipitation, temperature) of the growing season were again broken down into autumn-winter (October, November, December, January, February), spring (March, April) and early summer (May, June) periods. The strength of the correlation was determined according to the correlation coefficient (r).

The precipitation of the growing season had a positive effect on the valorigraph value in each maturity group, and the correlation was strong (early maturity group: 0.529**, mid-season maturity group: 0.532**, late maturity group: 0.619**). In all three maturity groups the early spring weather had a rather negative effect on the baking value of winter wheat varieties, and the correlation was rather strong (early maturity group: -0.783**, mid-season maturity group: -0.750**, late maturity group: -0.809**).

Negative correlation was found between the spring weather and the wet gluten content. The strength of correlation was rather strong in the case of varieties in the early maturity group (-0.754**), and it was strong in the case of varieties in the mid-season maturity group (-0.685**), and the late maturity group (-0.619**).

Strong negative correlation was found between the spring precipitation (early maturity group: -0.595**, mid-season maturity group: -0.559**, late maturity group: -0.622**), the autumn-winter- (early maturity group: -0.507**, mid-season maturity group: -0.502**, late maturity group: -0.585**), and spring temperature (early maturity group: -0.609**, mid-season maturity group: -0.605**, late maturity group: -0.594**) and the gluten deformation, which was a favourable effect. As regards the meteorological parameters, the gluten deformation of the wheat varieties in the different maturity groups was unfavourably affected by the early summer temperature, which was represented by rather close positive correlation (early maturity group: 0.830**, mid-season maturity group: 0.784**, late maturity group: 0.749**). The symbol „**” represents 1 %, and „*” 5 % significant correlation.

4.3.4. Complex qualification of winter wheat varieties

In my dissertation I compared the winter wheat varieties according to four (valorigraph value, wet gluten content, gluten deformation, Hagberg's falling number) quality parameters using Györi's Z-index method. According to maturity groups, Györi's Z index values given for the valorigraph number, wet gluten content, gluten deformation and Hagberg's falling number and the Z-values calculated from these four parameters were included in a table (*Table 7*).

In the early maturity group GK Öthalom, GK Kalász and Mv Emese had the best Györi's Z index (75). Considering the four examined quality parameters, Flori 2 and Rusija had the best results (60) within the group. The total number ranged between 60 and 75 in the case of mid-season varieties as well. GK Miska (75) proved to be the best-quality variety. GK Marcal, Róna and Buzogány had lower rates (60). In the late maturity group Györi's Z index values were similar to those in the former two maturity groups. As regards the total score, Carlo had the highest (75), while Gaspard had the lowest (55) value.

Out of the varieties listed above, the best varieties of the maturity groups are those (GK Öthalom, GK Kalász, Mv Emese, GK Miska, Carlo), which produce good quality yield under the ecologic potentials of the Hajdúság region, so they can be recommend to farmers who want to produce good quality winter wheat in this region. All in all, it was found in the case of each maturity group that, out of the quality parameters used to calculate the Z-index of winter wheat varieties, valorigraph value, wet gluten content and gluten deformation determine the change of this complex number. Hagberg's falling number has the smallest effect on the Z-index, as it was practically constant in each maturity group.

Table 7: Győri's Z-index values of early, mid-season and late winter wheat varieties (Debrecen-Látókép, 2001-2005)

Early maturing varieties					
Variety	Points	Points	Points	Points	Sum
GK Őthalom	25	25	10	15	75
Alföld 90	20	25	10	15	70
Kompolti 3	20	25	5	15	65
GK Élet	20	30	5	15	70
GK Kalász	25	25	10	15	75
GK Garaboly	20	25	10	15	70
Flori 2	15	20	10	15	60
GK Verecke	20	25	10	15	70
Abony	15	20	10	10	55
Mv Dalma	15	25	10	15	65
Mv Palotás	20	25	10	15	70
Mv Emese	25	20	15	15	75
Ukrainka	25	20	10	15	70
Rusija	20	25	5	10	60
Average	20	25	10	15	70
Mid-season varieties					
Variety	Points	Points	Points	Points	Sum
GK Marcal	15	20	10	15	60
Mv Magvas	25	20	10	15	70
GK Cipó	20	20	15	15	70
Róna	15	20	10	15	60
Hunor	20	20	15	15	70
Buzogány	15	20	10	15	60
GK Miska	25	25	10	15	75
Mv Csárdás	15	30	5	15	65
GK Petur	20	20	15	15	70
GK Rába	20	20	10	15	65
MF Kazal	20	15	15	15	65
Average	20	20	10	15	65
Late varieties					
Variety	Points	Points	Points	Points	Sum
Gaspard	15	20	5	15	55
Mv Magdaléna	15	30	5	15	65
Maximus	20	25	5	15	65
Ludwig	20	30	5	15	70
Carlo	20	30	10	15	75
Capo	15	25	5	15	60
Average	20	25	5	15	65

4.4. Complex evaluation of winter wheat varieties

In winter wheat production the objective of the farmer is to produce high yields and good quality. However, in most cases these two significant factors do not go parallel in a given winter wheat variety. Either high yield is provided with lower quality, or the quality is good but the yield is average or even lower.

Figure 1 tries to assist farmers growing winter wheat in the Hajdúság region. On the average of five years broken down according to maturity groups it depicts the crop yield and Győri's Z-index, which includes the different quality parameters in one diagram.

The best varieties are those with high yields and high Z-index at the same time. These varieties are depicted in the upper right corner of the diagram, while the varieties with average or lower yields and Z-index values are in the lower left corner.

In the early maturity group on the average of five years under the ecologic potentials of the region, GK Garaboly, Ukrainka, GK Kalász, GK Verecke and Mv Palotás had outstanding yields and good quality. We have to mention Mv Emese and GK Öthalom, which gave average yields and good quality.

In the mid-season maturity group averaging the five years GK Cipó, Mv Magvas, GK Miska and GK Petur had good quantity and good quality at the same time.

Within the late maturity group, the varieties representing high yields and good quality are separated. As regards product yield Gaspard (with low quality), while as regards quality (with low yields) Carlo proved to be outstanding. In the late maturity group on the average of five crop years only Ludwig produced good quality and quantity at the same time.

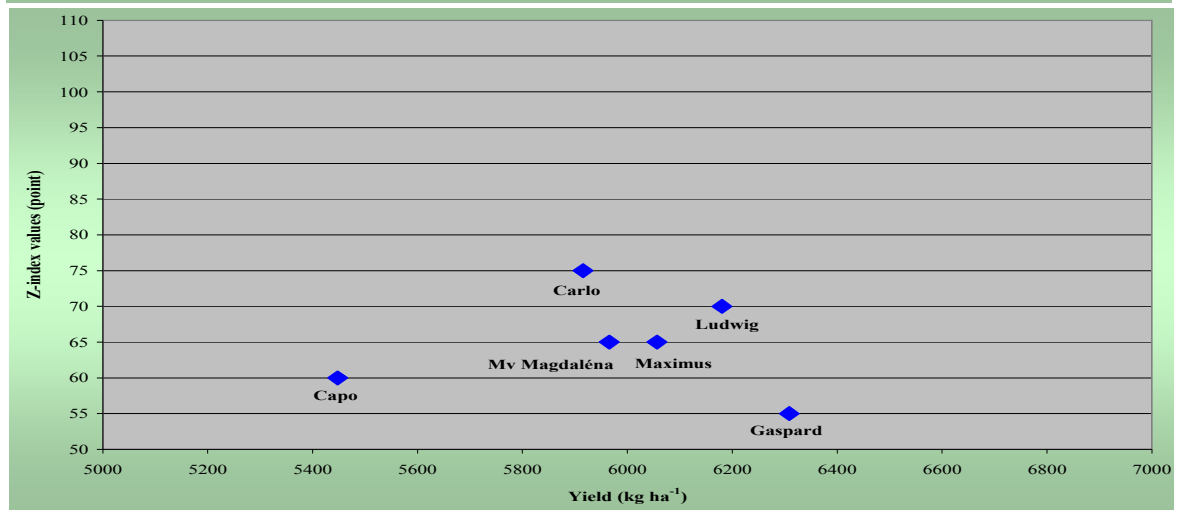
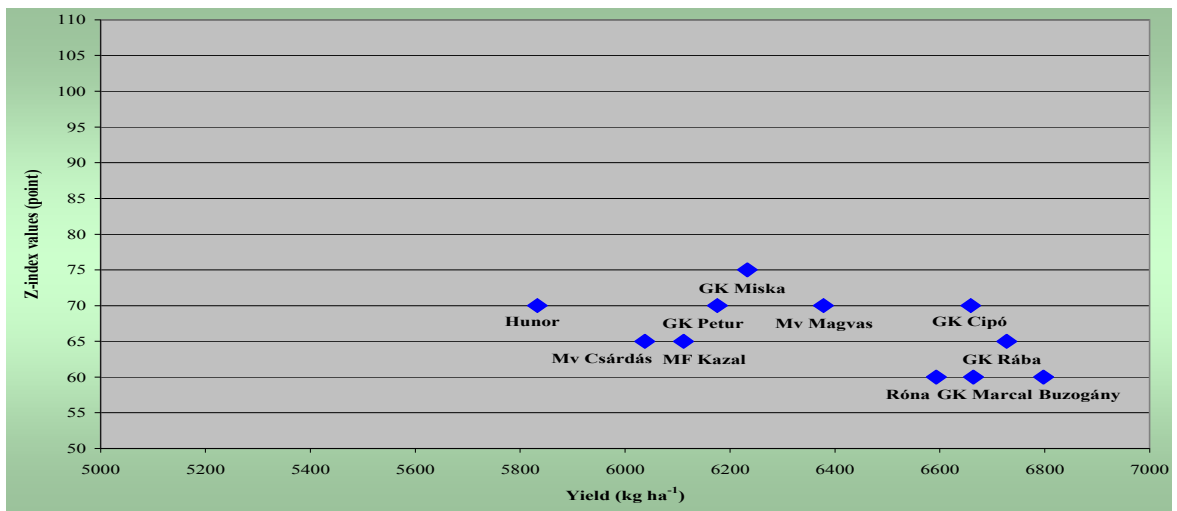
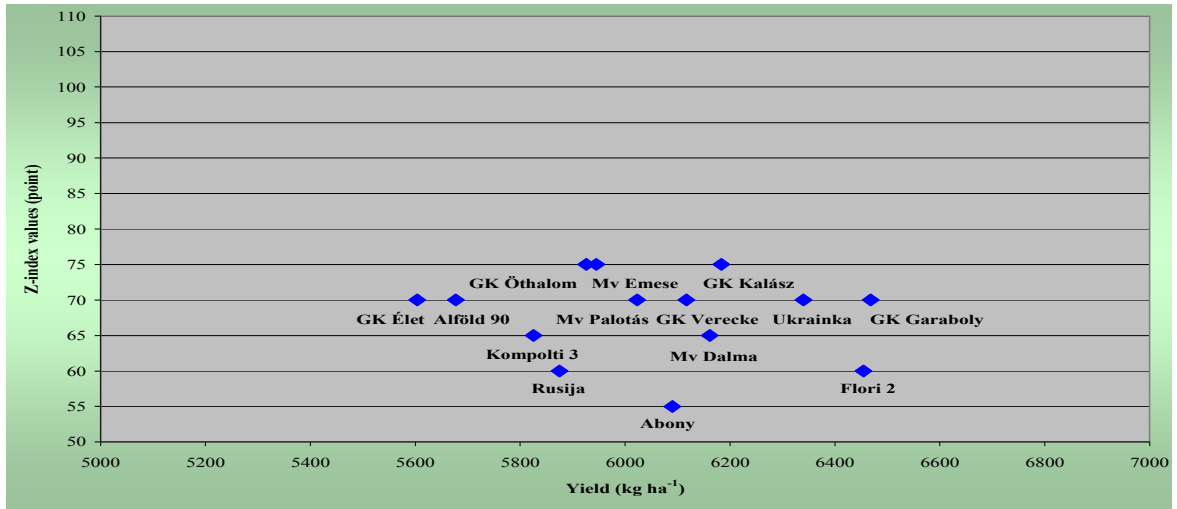


Figure 1: Complex evaluation of early, mid-season and late winter wheat varieties (Debrecen-Látókép, 2001-2005)

5. NEW SCIENTIFIC RESULTS

1. Taking given ecologic and agrotechnical circumstances, on the average of the crop years mid-season winter wheat varieties had 5-7% higher yield than the varieties in the early and late maturity groups.
2. Crop year is most important influencing factor in determining the yield of winter wheat varieties, which was proved by the fact that the yield fluctuation of the highest-yielding varieties ranged between 63.4% and 103.8%.
3. On the average of many years, the valorigraph value (by 5-9 %) in the early maturity group, the wet gluten content (by 5-12 %) and Hagberg's falling number (by 6%) in the late maturity group and the gluten deformation in the mid-late maturity group (by 10-30%) proved to be the best.
4. Kang's stability analysis proved that an extreme crop year decreases yield- and quality stability in winter wheat production. The linear regression coefficient of varieties with good yield and quality stability is below 0.9. More than half of the examined varieties had unfavourable linear regression coefficient lower than 0.9, i.e. the yield stability of these varieties was poor.
5. In the linear regression equation ($y = 0.8054x + 876.12$, $R^2 = 0.9490-0.9816$) of varieties with good yield stability (Alföld 90, Mv Palotás, Mv Emese, Hunor, Capo) the mean linear regression coefficient (0.8054) was much lower than in the equation ($y = 1.1472x + 785.92$, $R^2 = 0.9142-0.9912$) of the varieties with poor yield stability (GK Garaboly, Kompolti 3, Flori 2, MF Kazal, Gaspard, Mv Magdaléna).
6. In the regression equation ($y = 0.7386x + 12.1473$, $R^2 = 0.5141-0.9741$) of varieties with stable valorigraph values (GK Öthalom, GK Garaboly, Rusija, Hunor, Buzogány, MF Kazal, Gaspard) the regression coefficient was 0.7386, while in the equation ($y = 1.3084x + 20,4020$, $R^2 = 0,0,8196-0,9658$) of varieties with less stable valorigraph value (Flori2, GK Verecke, Róna, Mv Csárdás, GK Marcal, Capo) this values was double (1.3084).
7. As a result of improving ecological circumstances, the genotypes with better yields (GK Garaboly, Flori 2, GK Kalász, Buzogány, GK Rába, GK Marcal, Gaspard) and quality parameters (GK Kalász, GK Miska, Carlo) had stronger responses, indicating that the stability of these wheat varieties is poorer.

8. Pearson's correlation analysis confirmed that the key determining factors of the crop yield of winter wheat varieties are the precipitation in the growing season (correlation coefficient (r) ranging between 0.703** and 0.722**). It was statistically proved that the high average temperature in early summer has an unfavourable effect on the crop yield (correlation coefficient (r) ranging between -0.838** and -0.885**) and valorigraph value (correlation coefficient (r) ranging between -0.750** and -0.809**). The wet gluten content of winter wheat varieties is negatively affected by above than average spring mean temperature (correlation coefficient (r) ranging between -0.619** and -0.754**).
9. By using the crop yield and crop stability values and Györi's simplified Z-index we determined those winter wheat varieties, which can safely be produced in different ecological conditions in the Hajdúság region.

6. PRACTICAL RESULTS

1. If the amount and distribution of precipitation and the mean temperature in the crop year are average, the yield of winter wheat increases. (In 2004: 8335 kg ha⁻¹ averaging the maturity groups). The sustained hot and draughty weather in spring is a serious yield-decreasing factor. (In 2003: 3210 kg ha⁻¹ averaging the maturity groups).
2. The sustained water deficit in the growing season and the above than average temperature in the maturing period had a negative effect on the baking value. (In 2003: 26.3 on average of the maturity groups). The yield of most varieties was only feed quality. Good water supply and average precipitation has a positive effect. (In 2005: 72.4 on average of the maturity groups).
3. Examining five years with different weather conditions – similar edafic conditions – the following hybrids had good gluten content and good stability as well: GK Élet (38.17%; 45.3%), Kompolti 3 (37.38%; 41.9%), GK Öthalom (34.89%; 39.2%), GK Kalász (35.33%; 45.2%) and Mv Palotás (35.79%; 45.4%) in the early maturity group, Mv Csárdás (39.60%; 38.0%) in the mid-late maturity group, and Maximus (36.28%; 35.6%) in the late maturity group.
4. The negative effect of a draughty crop year was confirmed by high wet gluten deformation values (5.8 – 8.6 mm) parallel with extremely high variations (235.3 % - 246.6 %). Only the mid-season variety of GK Petur (4.5 mm, 100.0 %) had acceptable gluten deformation and variation values.
5. Under the ecological conditions of the Hajdúság loess plain the early maturing variety of GK Öthalom (75), GK Kalász (75) and Mv Emese (75), the mid-season GK Miska (75), and the late Carlo (75) had the best Győri's Z-index, i. e. these varieties can achieve good results in several quality parameters as well.
6. Under the ecological conditions of the Hajdúság loess plain concerning the crop yield and the complex quality, the varieties with high yield safety are the early variety of GK Garaboly, Ukrainka, GK Kalász, GK Verecke and Mv Palotás, the mid-season GK Cipó, Mv Magvas, GK Miska and GK Petur, and the late Ludwig.

Related publications to the subject of the thesis:

IF publications

1. **ÁGOSTON T.** – Pepó P. (2005): Effects of genetic and ecological factors on yield formation in winter wheat production. *Cereal Research Communications*, 33. 1. 37-40. (IF: 0,32)
2. **ÁGOSTON T.** (2006): Evaluation of quantity and quality parameters in winter wheat varieties. *Cereal Research Communications*, 34. 1. 373-376. (IF: 1,037)

Non-IF reviewed publications

1. Pepó P. – Zsombik L. – Szabó A. – **ÁGOSTON T.** (2003): Hybrid-specific weed control in maize production. 3rd International Plant Protection Symposium at Debrecen University. Proceedings. Ed.: György J. Kövics. 294-299.
2. **ÁGOSTON T.** (2004): Effect of crop year on the yields of wheat varieties. Proceedings of the III. Alps-Adria Scientific Workshop, Dubrovnik, (Ed.: Sz. Hidvégi-Cs. Gyuricza) 2004. 25-29.
3. **ÁGOSTON T.** – Pepó P. (2004): Őszi búza fajtatesztelési eredmények a 2002/2003 tenyészciklusban a Hajdúságban. Debreceni Egyetem, Agrártudományi Közlemények 13. *Acta Agraria Debreceniensis, (Szerk.: Jávora A.)* 2004/13 Különszám, 59-65.
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4. **ÁGOSTON T.** - Pepó P. (2005): Őszi búzafajták növénykórtani vizsgálata a Hajdúságban. In: XI. *Ifjúsági Tudományos Fórum. CD Kiadvány. Szerk.: Lengyel Zoltán. Veszprémi Egyetem Georgikon Mezőgazdaságtudományi Kar, Keszthely 2005. március 24. VI. 601/1-5.*

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1. Pepó P. – Zsombik L. – Szabó A. – **ÁGOSTON T.** (2005): Technológiafejlesztési feladatok és lehetőségek a hazai búzatermesztésben. *MezőHír*. 9. 2005.9.2., 24-28.
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