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Breeding for Adaptation Traits of Wheat in Eastern European Environments the Hungarian Example

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ABSTRACT

The traditional wheat germplasm that have evolved in Eastern Europe exhibit a unique adaptation type due to the ecological conditions. Bread wheat type developed in this region is a valuable source for wheat breeders worldwide. Wheat improvement in the 20th century was carried out using traditional breeding methods and the consideration of environmental effects played a significant role in the germplasm development. Efficient wheat breeding programme for continental climatic environments will require new breeding efforts, including new strategies in gene bank research, to develop new germplasm in pre-breeding programmes and the application of modern breeding technologies. The complex tasks facing wheat breeders in Eastern Europe include the improvement of stress resistance, especially winter hardiness and tolerance of drought and heat at higher levels of yield potential. New challenge is to close the yield gap in the changing climate. The good bread making quality of Eastern European wheat will only represent an advantage if it is associated with better quality stability.

Keywords: Wheat, pre-breeding, adaptability, yield gap, bread making quality stability.

Introduction

Changes in the Eastern European Wheat Type

A significant segment of cereal production takes place in suboptimal agro-ecological environments in the World. This fact is especially true in the Eastern European regions where the tendency to drought, the uneven rainfall distribution, the continental climate and the great variety of soil types have made a traditional contribution to the development of a wheat type suitable for low-input environments. These climatic conditions are mainly characterised by extreme variability and unpredictability. Geographical and climatic factors have had a substantial influence on the genetic background of the germplasm and on agronomic management practices.

Landraces have played an important role in the development of the East European wheat germplasm. Special mention should be made of the landrace Bánáti (or Bánátka), originating from the area which is now on the borders of Serbia, Romania and Hungary, and which was made use of by wheat breeders in Russia (Vavilov 1935), Ukraine, Romania and Hungary. The Polish landraces Sandomierka (Strebeyko 1976) and Galicia (from a region now in West Ukraine) (Lelley 1967) were not only the parental populations for a large number of East European wheats, but were also taken to North America by emigrants in the 19th century. The Galicia landrace was also the ancestor of the Hungarian landrace Tiszavidéki (called Teiskaya in Russia), the progeny of which spread at the end of the 19th century to South Russia, to the Kuban region, and also to parts of the North Caucasians (Jakubziner 1962), while also being one of the parents of the Bánkúti wheat varieties, known for their excellent breadmaking quality.

In the winter wheat zone, the development achieved by Lukyanenko, who selected the variety Bezostaya 1 in Krasnodar, led to excellent results in the Eastern European region after the second world war. The good adaptability of Bezostaya 1 could have been due in part to the fact that its parents originate from different ecological regions of the World. With the selection of this variety, yields were increased in the Krasnodar region of Russia by 2.5 times (Dorofeev and Udachin 1987). In the northern zone of winter wheat production, the extremely winter-hardy variety Mironovskaya 808 became the dominant variety in the northern part of Ukraine, and also occupied large areas in Poland and Czechoslovakia in the 60s and 70s of the last century. The Krasnodar-bred varieties Avrora and Kavkaz, which carry the 1B/1R rye translocation containing the resistance genes Pm8, Lr26, Sr31 and Yr9, represented a great genetic advance in yield potential (Bedő *et al*., 1993). Similar conclusions were drawn by Javornik *et al*., (1991) when analysing 1B/1R translocation varieties such as Yugoslavia, Balkan and Zvezda in Serbia. However, despite the positive effects of wheat-rye translocations on yield and adaptability traits in Eastern Europe, their deleterious effect on breadmaking quality cannot be completely eliminated. The further use of this germplasm in wheat breeding may be limited, as the new stem rust (*Puccinia graminis tritici*) race Ug99 exhibits broad virulence, being able to overcome the stem rust resistance gene Sr 31, located on the 1B/1R translocation (Singh *et al*., 2007).

Daylength insensitivity, race-specific disease resistance and better lodging resistance contributed to the better adaptability and widespread cultivation of modern types of varieties in the second half of the last century. From the 1970s onwards, Ukrainian wheat breeders endeavoured to reduce plant height (Litvinenko 1998). Russian wheat breeders in Krasnodar aimed chiefly at winter hardiness and favourable technological quality, so they made use of Krasnodarskii karlik, developed by mutation breeding from Bezostaya 1 (Bespalova 1996), while Romanian breeders used Rht1 (Saulescu *et al*., 1988). In Hungary the Rht1 and Rht8 genes proved successful. In Serbia Rht8, originating from the Japanese variety Akakomughi, and Rht1, derived from Saitama 27, can be detected in semi-dwarf wheat varieties (Borojevic 1990). These genes cause less dwarfing than the joint presence of Rht2 and Rht1 in a number of West European varieties, but due to the drier climate and the lower nutrient supply levels, their use was a realistic solution for the development of semi-intensive wheat.

As growing conditions improved and chemical input increased in the second half of the last century, breeders endeavoured to develop genotypes with a higher ratio of reproductive organs. Positive correlation was found between the grain yield and the harvest index (r=0.92) in Martonvásár (Szunics *et al*., 1985). The statistical analysis of data collected over many years proved that the year (environment) had a substantial effect on the grain-straw ratio of the varieties examined, though the varieties responded differently to ecological factors. Lukyanenko (1966) considered a 1:1 grain-straw ratio to be ideal. The harvest index increased in many parts of the East European region as a result of breeding efforts. Szunics *et al*., (1985) found a 47% harvest index due to selection efforts focused on an increase in plant productivity and a decrease in plant height.

Yield progress and improved adaptability traits contributed to an annual yield increase of 0.86% in Russian spring wheat varieties between 1920 and 1999 (Vassiltchouk 1999). The genetic progress for yield in Romanian wheat varieties was estimated by Saulescu (1998) to be 50 kg/ha/year. In Hungary, studies on the period between 1965 and 1985, when national yield averages grew to the greatest extent, reveal that the varieties were responsible for 42–45% of the total yield increment (Szunics *et al*., 1985).

The type of wheat developing in the East European region was not uniform. Despite the similarities, there were also substantial differences as a consequence of the diverse ecological conditions. In general the winter type is dominant, but spring wheat varieties spread in several of the central and East European regions of Russia (e.g. in the Volga and Ural regions), where abiotic stress resistance is a decisive factor. In these regions, variety change progresses at a slower rate. The great extent of diversification is demonstrated by the fact that selection is carried out for four different adaptation types in Krasnodar, the largest Russian wheat breeding centre, including both semi-intensive drought-resistant types and semi-dwarf wheat types (Bespalova 1996). In accordance with the duration of the vegetation period and adaptation to soil and climatic zones, Ukrainian wheat varieties can be divided into three fundamental groups, so breeding is underway for intensive, semi-intensive and widely adapted wheat varieties (Lyfenko 1987).

The yield increases recorded between 1960 and 1990 stagnated the last decade of the 20th century and first decade of the 21st century in many regions of Europe, and this situation was characteristic in most East European regions too. This can be attributed to a number of factors, including

• The low level of fertilizer and pesticide applications, which resulted in a lower yield and quality traits stability. The use of technical inputs declined partly due to growing input costs. The strengthening demand for sustainability and environmental protection have also led to a reduction in the use of chemicals (Figure 1).

• Large differences among growing seasons due to the climate change caused more negative effects on wheat production than in many other regions of the World.

Breeding For Adaptability Traits of Wheat in Martonvásár, Hungary

Wheat breeding programmes initiated in Hungarian plant breeding institutes after the second world war developed a whole series of varieties in Martonvásár and in Szeged. Bread wheat improvement in the 20th century was carried out using traditional breeding methods. However, new genetic, pathological and physiological knowledge have significantly contributed to a better understanding of this crop. It has become evident that the next generation of wheat genotypes will need to be developed for better adaptability traits and that further crop improvement will require new breeding tools. It has become important to select wheat genotypes adapted to changing climatic conditions, as a return to old varieties is not an option for future development. Martonvásár small grain cereal breeding programmes established breeding strategy to improve research efforts, including strategies in gene bank research and research efforts to develop new germplasm in pre-breeding programmes.

Gene Bank Research

The role played in plant breeding by the old varieties and populations stored in gene banks has increased recently. One of the richest collections in the World and in Eastern Europe is located in the Vavilov Institute of Plant Industry in St. Petersburg, Russia. The efficiency of plant gene bank research programmes depends on the accuracy and precision of evaluation techniques. The evaluation of large germplasm materials using only traditional tools such as geographic origin, pedigree information, and botanical and agronomic descriptions has become less efficient.

The establishment of a cost-effective core collection to represent the genetic variability of large collections is of vital interest in Eastern Europe, where traditionally large germplasm collections have been available to breeders. Core collections are useful materials for the association mapping of disease resistance, seed quality and domestication-related traits. A good example is the core collection of 372 accessions based on passport and simple sequence repeat (SSR) marker data selected by Balfourier *et al*., (2007) in the Clermont-Ferrand Genetic Resources Center (INRA) to explore the diversity in wheat accessions. Genetic resources are suitable materials for association mapping when breeders analyse low heritability traits like yield components (Breseghello and Sorrells 2006).

The efficiency of gene bank research can be improved through the joint application of new methods of genotyping and phenotyping, which enable plant breeders to screen the collections for genes important for breeding, identify unique alleles and characterize genetic resources at the gene level, dissect the populations of old landraces and wild relatives to provide insights into the allelic content of potential germplasm for use in breeding.

Screening wheat genetic resources, molecular markers are efficient tools for identifying agronomically important genes. In the course of gene bank research in Martonvásár, pedigree analysis revealed that the variety Bezostaya 1 is frequently present in the wheat germplasm. According to Dyck (1994) Bezostaya 1 carries the Lr34 leaf rust resistance gene, which ensures a medium level durable resistance. When it is combined with other Lr genes, is an efficient component of leaf rust resistance. Vida *et al*., (2009) carried out analysis with molecular markers and they proved that the Lr34 resistance gene is significantly present in the Martonvásár germplasm of the 226 genotypes screened (Table 1).

The identification of unique alleles from genetically heterogeneous old populations play an important role in developing new germplasm for breeding. A unique allele was identified with the help of a gene-specific primer from the Bánkúti 1201, an old Hungarian variety population. In the course of the analysis a fragment characteristic of Bánkúti 1201 was identified and the nucleotide sequence was determined. This showed the presence of a 1Ax2* high molecular weight (HMW) glutenin gene variant which, despite near homology, differed from the original 1Ax2* gene at one important point. Nucleotide exchange involving the exchange of serine for cysteine was observed at 1181 bp in the 1Ax2* sequence (Juhász *et al*., 2003). This change resulted an extra sulphydryl group which facilitates the formation of further disulphide bonds, might lead to an improvement in gluten quality characters.

The dissection of the heterogeneous population and the development of sublines contribute to the exploitation of existing variation for different agronomic traits. For example, the analysis of 216 sublines from the Bánkúti 1201 revealed six HMW glutenin subunit types and 19 different gliadin types. Significant variation was detected involving the overexpression of the Bx7 HMW glutenin subunit and the unextractable polymeric protein % (UPP%) (Juhász *et al*., 2003). Marchylo *et al*., (1992) reported that at least two types of Bx7 protein existed in different varieties, and designated the Cheyenne type, leading to normal protein production, as 7^* and the overexpressed Glenlea type as 7. The quality of the Canadian variety Glenlea can also be attributed in part to the Bx7 subunit (Cloutier and Lukow 1998), though in this case the gene is only present in a single copy. Overexpressed Bx7 HMW glutenin subunits have also been detected in many other wheat genotypes, both in old landraces and in modern varieties (Marchylo *et al*., 1992). Analyses carried out by Butow *et al*., (2004) demonstrated that the allele responsible for 1Bx7 HMW glutenin overexpression in the Canadian prime hard red spring wheat Glenlea is also present in certain sublines of Bánkúti 1201, providing an indirect confirmation of the fact that East European germplasm may also have had an influence on the development of North American varieties. The rheological analysis of lines isolated from old varieties and carrying the 1Bx7 HMW glutenin overexpression gene showed that selection for this trait may contribute to the breeding of varieties with excellent gluten quality in Eastern Europe.

New Germplasm Development in Pre-breeding

One consequence of commercial breeding in the second half of the 20th century is that differences between alleles in modern elite varieties are diminishing, and the development of new germplasm in pre-breeding programmes has become important. Different types of genetic resources are available in East European wheat breeding for the development of new germplasm. In commercial breeding programmes breeders use mainly adapted varieties and lines to achieve fast breeding progress and select new registered varieties. The application of old landraces, wild and cultivated relatives need more time, however the chance of broadening genetic variation is better.

The transfer of useful genes is complicated by crossing barriers in the case of wild or cultivated related species, by the absence of pairing between homologous chromosomes, etc. To avoid embryo or endosperm abortion after successful fertilisation *in vitro* techniques such as ovule culture or embryo rescue are applied. It often happens that the F_1 plants from interspecific crosses are sterile. Many methods have been introduced to overcome incompatibility between the species and achieve successful hybridisation. These include doubling the ploidy level, protoplast fusion, etc. Colchicine treatment was applied to F_1 hybrids to induce chromosome doubling in order to produce synthetic hexaploid wheat. The use of a genome homozygous for the crossability alleles (*kr1kr1kr2kr2*) may contribute to higher seed set when wheat is crossed with rye, barley, etc. The recessive crossability allele *kr1* was transferred from the spring wheat cultivar Chinese Spring (CS) into the winter wheat cultivar Martonvásár 9 (Mv9) by backcrossing Mv9×CS hybrids with Mv9. As a result of five backcrosses with Mv9 and two selfings after each backcross, the selected progenies had over 50% seed set with rye when tested on a large number of individual plants (Molnár-Láng *et al*., 1996).

The introduction of alien gene into adapted wheat germplasm is time-consuming using traditional breeding methods. A good example of this are wheat varieties carrying the 1B/1R rye translocation, which required 33 years from the first cross of parents to the registration of the first variety (Rabinovich 1998). Pre-breeding for adaptational traits is efficient if breeders are able to widen the genetic variation and to shorten the selection time. One method which has been routinely introduced in Martonvásár is the doubled haploid technology 30 years ago to produce homozygous progenies from the F_1 generation in a single step (Bedő *et al*., 1988). This technology is an excellent tool not only for cultivar development, but also for pre-breeding and for the establishment of mapping populations.

Despite the complex nature of the breeding process, wild relatives have frequently been used by East European wheat breeders. In Russia Tzitzin selected winter wheat varieties from *Agropyron* sp. × *T. aestivum* crosses and they were grown in commercial production (Zhukovsky 1957). Interspecific crosses were used to incorporate a number of disease resistance and storage protein genes into the common wheat germplasm in the Odessa breeding programme (Litvinenko *et al*., 2001).

Today one of the most promising breeding technologies to accelerate the introduction of alien genes into wheat from wild relatives is cisgenesis. It has great potential to overcome many problems of traditional breeding, such as linkage drag, crossing barriers, the introduction of many deleterious genes linked with one useful gene. This method differs from transgenesis that DNA fragments from cross-compatible species are incorporated into the genome, so cisgenic plants do not contain foreign or modified genetic material. As wheat has many wild and cultivated relatives, the prospects for developing precision breeding via the cisgenesis technology are excellent.

This technology would be a modern alternative to traditional breeding and would offer an ideal way of incorporating genes of adaptation traits from wild and cultivated wheat relatives into common wheat.

The use of molecular markers for the development of new germplasm and to improve the efficiency of pre-breeding is a great step forward in breeding. On the one hand it allows breeders to accelerate the introgression and backcrossing of genes into diverse genetic backgrounds, while on the other hand they can use it to pyramid genes with similar phenotypic effects. This technique is particularly useful for the incorporation of resistance genes. The advantage of marker assisted selection (MAS) in early generations is that heterozygous progenies with valuable recessive genes are not discarded, thus contributing to the fixation of recessive genes. To exploit this advantage, the use of MAS in early generations and phenotypic selection in later generations are suggested. MAS can substitute for phenotypic selection in conditions unfavourable for phenotyping, or against stress factors not present in the breeding location or appear only rarely. This technique is not affected by the environment, which means that it is less season-dependent than phenotypic selection.

Marker-assisted backcross breeding (MABC) is one of useful tools to accelerate the introgression of adaptation traits. Simulating recombination during meiosis proves that breeders can recover recurrent parent with molecular markers more efficiently compared to traditional backcrossing (Frisch *et al*., 2000). MABC provides efficient positive foreground selection for the donor trait, positive background selection for the recurrent parental genome and negative background selection against undesirable donor parent alleles. After three backcross (BC) generations it was possible to select genotypes with useful agronomic trait similar to that of the donor line (Figure 2). MABC will be a useful breeding method to introgress transgenes into elite germplasm, which will permit the rapid deployment of agronomic traits.

Molecular markers offer a precise selection for pyramiding genes for resistance to diseases. They were employed for the transfer of leaf rust resistance genes in the framework of the BIOEXPLOIT FP6 EU project (Vida *et al*., 2009). The choice of the Lr genes was based on their effectiveness and how closely linked PCR markers were available. The agronomic traits of BC_5 and BC_6 lines are very similar to those of the recurrent parents. Eleven pyramided gene combinations have been developed, and a doubled haploid programme has been set up in order to stabilize the gene combinations.

Stem rust is one of the most destructive diseases of cereal crops worldwide. During the last period a new aggressive virulent stem rust group of races Ug99 cause severe losses in some wheat growing regions of the World. However, this race is not present in Eastern Europe until now. We carried out pre-breeding studies about the genetic background of stem rust resistance in the Martonvásár gene pool and we selected new genotypes resistant to these virulent stem rust races. In international experiments Mv Zelma was found to be resistant to Ug99 related pathotypes. Preliminary data indicated that its resistance gene is located on 7A chromosome. Resistance genes Sr15 and Sr22 are located on this chromosome. Infection types and map location suggest that the gene in MV Zelma is not Sr22. It is probable that this gene could be a second allele of Sr15 that provides Ug99 resistance (Nava *et al*., 2012).

One of the most important criteria for germplasm development in Eastern Europe is above-average abiotic stress resistance. This includes winter hardiness, which involves different components in different regions of Eastern Europe. One of these components is late winter frost resistance, which has been studied in the Martonvásár phytotron for several decades (Veisz *et al*., 2001). The analysis of wheat varieties characteristic of diverse regions of Europe revealed (Bedő *et al*., 2005) that East European varieties were the most resistant, South European varieties the most frost-sensitive and West European wheats were intermediate for frost resistance.

The importance of winter hardiness, and especially of frost resistance, is proved by the fact that over the last century a large part of the area previously sown to spring wheat in Russia was gradually occupied by winter wheat. While spring wheat was grown on around 80% of the European region of the country in the first two decades of the 20^{th} century, this ratio had dropped to 62.4% by the 1980s. However, a high level of winter hardiness is required in these areas if production is to be reliable (Dorofeev and Udachin 1987). Due to the negative grain yield/frost resistance correlation, varieties with poorer winter hardiness are spreading in Ukraine, if the frost resistance of the varieties grown in 1985 is compared with the situation 15 years later. By the turn of the millennium none of the varieties could equal the winter hardiness of Odesskaya 51, demonstrating the importance of breeding for winter-hardy germplasm (Litvinenko *et al*., 2001).

The most complex task facing East European wheat breeders is the improvement of drought and heat tolerance, or its maintenance in new germplasm at a higher level of yield potential. In Ukraine drought-resistant genotypes have high vernalisation requirement and low photoperiod sensitivity. They should have intensive nodal root growth in early spring, active root development during double ridge formation, leaves with high osmotic adjustment and the active remobilisation of non-structural carbohydrates to the kernels during the grain-filling period (Litvinenko 1998). In regions prone to drought, adaptability, drought tolerance and yield are closely related traits. In the southern parts of Romania, selection for earliness is one way of avoiding drought and improving yield stability (Saulescu *et al*., 1998). The role of environmental effects depends on the developmental stage of the plant, and may influence both yield and grain quality properties. Breeding for improved heat and drought stress tolerance during meiosis and anthesis remains a significant challenge.

Selection for better adaptability has become particularly important in the light of climate change, especially with the increasing frequency of extreme weather events (Veisz *et al*., 1996). Greater fluctuation is observed not only between regions, but also between years. Price volatility during the recent period is also influenced by unstable yield.

Regardless the fact that drought and heat are the main abiotic stresses in wheat production, extreme weather conditions, like heavy rainfall during the harvest period, can cause the premature germination of seeds, known as preharvest sprouting (PHS). This phenomenon became more frequent during the climate change and it is a serious problem in Eastern Europe too. Especially wheats with white-colored grain are particularly susceptible. PHS has a negative effect on grain yield but it also reduces bread-making quality through the breakdown of starch reserves in the endosperm by the increased enzyme activity of alpha-amylase.

The high yield gap between the potential yield and farm yield is one of the consequences of the lower level of yield stability. To determine the difference between the potential yield and farm yield we set up a three-year small plot experiment carried out with registered varieties widespread in the commercial production in Hungary. The experimental plots were treated with herbicide and fungicides and 240 kg/ha mineral fertilizer - nitrogen, phosphorus and potassium in 2:1:1 ratio - were applied. The difference between the farm yield - characterized by the national average yields - and the potential yield was 48.2% in average of the 3 year results in Hungary (Figure 3). Investigations made by Litvinenko *et al*., (2001) showed that the potential yield of new varieties rose from 2.73 t/ha in the second decade of the 20th century to 6.74 t/ha in the 1980s, based on the results of small-plot experiments. At the same time, the average wheat yield in Ukraine was only 3 t/ha even in favourable years, and was even less at the turn of the millennium. This is less than half of the potential yield. Among the West European countries, the yield gap in the UK is

30%, indicating that the potential yield of the wheat varieties is better exploited (Fischer and Edmeades 2010).

Technological quality stability is a particularly critical property in Eastern Europe because, in general, wheat with better breadmaking quality and higher protein content can be grown in the region than in Western Europe. The vast majority of wheat varieties belong to the hard red quality group, based on the North American classification, although each country has its own quality standard. Over the last two decades the stability of quality parameters has deteriorated due to the negative effects of reduced mineral fertiliser use, extreme climatic conditions and biotic stress factors (e.g. *Eurigaster* sp.). The concept raised by Canadian plant breeders (DePauw *et al*., 1998), who suggested that endeavours should be made to change the composition of the storage protein for new types of industrial uses rather than increasing the protein content, would definitely be worth considering in the course of new germplasm selection for better quality adaptability.

Wheat breeding programme in Martonvásár has been focussed on bread-making quality and quality stability in order to preserve the good quality traditionally characteristic of Hungarian wheat, which is capable of exploiting Eastern European environmental conditions to give good quality with satisfactory stability. The Pannonia quality wheat R&D system, a complex national project was established in 2000 for the management of research and development on wheat quality. As a result of the programme technological quality categories were established, taking into consideration the major quality classifications used in the global cereal industry and the high protein quality of the hard red type of wheat traditionally grown in Hungary. The Pannonian premium and Pannonian standard categories both have criteria to exploit the advantages of the Hungarian germplasm and environmental conditions to produce wheat of a quality satisfying the demands of both domestic and export markets. In order to validate the new quality categories and the quality level expected from them, a trade-mark has been registered (Bedő 2008).

Despite the fact that genetically modified wheat development is limited because of public concern, especially in case of small grain cereals, well-established transformation protocols are already available for wheat, involving increasingly efficient *Agrobacterium*-mediated transformation techniques, better integration patterns and improved co-transformation. The rapid development of the transgenic breeding technology for various agronomic traits is proved by the increasing number of traits tested in field trials in North America (Dunwell 2008). Breeders from Martonvásár carried out joint analyses on genetically modified (GM) wheat in cooperation with scientists from Rothamsted. This collaboration is focussed on high-molecular-weight (HMW) glutenin subunits to increase dough strength, which is one of the quality stability traits for breadmaking. According to the results of field experiments on GM spring wheats over-expressing HMW subunits 1Ax1 and 1Dx5, led to significant changes in the structure of the glutenin polymers which were detected in flour functional properties, caused by the altered ratio of x-type to y-type HMW subunits. The expression of the subunit 1Ax1 transgene led to increased dough strength, while the expression of the homologous subunit 1Dx5 transgene led to "overstrong" dough with low extensibility and poor water absorption (Rakszegi *et al*., 2008).

Seed Policy and Production Stability

Through the breeding programmes initiated in Hungarian Pant Breeding institutes a whole series of varieties were developed, first in Martonvásár and in Szeged, while other varieties of foreign origin are also grown because of the liberal seed market policy of the European Union. The area sown to Hungarian-bred varieties occupy about 50% of the wheat-growing area in the middle of the second decade of the 21st century.

The number of varieties cultivated gradually rose after entering the European Union in 2004. Beside the wheat varieties registered in Hungary, wheat varieties registered in other countries of the European Union are also allowed to produce in Hungary. The higher number of wheat varieties potentially a useful tool to increase biodiversity in the wheat production, however the agronomic properties of unknown wheats, mainly their adaptation to the Hungarian climatic conditions are questionable. The twenty most popular varieties occupy around 50-60% of the total growing area. Even the most successful varieties are rarely grown on more than 10% of the sowing area. Over the last few decades there has been little change in the 5–6-year average life-span of the varieties, which is 6-7 years when weighted with the sowing area.

Concerning the seed industry, the centralised seed supply system was discontinued in 1990 when the market oriented economy was introduced. Although the land changed hands, the majority of the seed multiplication farms continued their activities regardless of the constant transformations. The restructuring of the seed market was accelerated by the fact that foreign breeding companies, which had for years been contracting farmers in Hungary to grow large quantities of seed, set up their own companies, which then entered the market. Leading breeding institutes in Hungary have adapted to the new market environment by establishing their own seed companies and by signing contracts with new market players. Their survival was greatly helped by the fact that Hungary has been a member of UPOV since 1983, which meant that variety rights were reliably protected even during the transitional period of the market oriented economy.

The structural changes were accompanied by a reduction in the use of certified seed. The state attempted to remedy this by providing discounts on seed purchases. For several years a certified seed level of around 50% was achieved by decreeing that these discounts were only available to farmers who sowed certified seed on at least 40% of their wheat fields. When Hungary joined the EU in 2004, however, all seed subsidies were discontinued, so the use of certified seed dropped to 25-30%. This new situation does not contribute to the yield and quality stability of wheat production.

Figure 1. Applied amounts of fertilizers in Hungary (years 1980-2010)

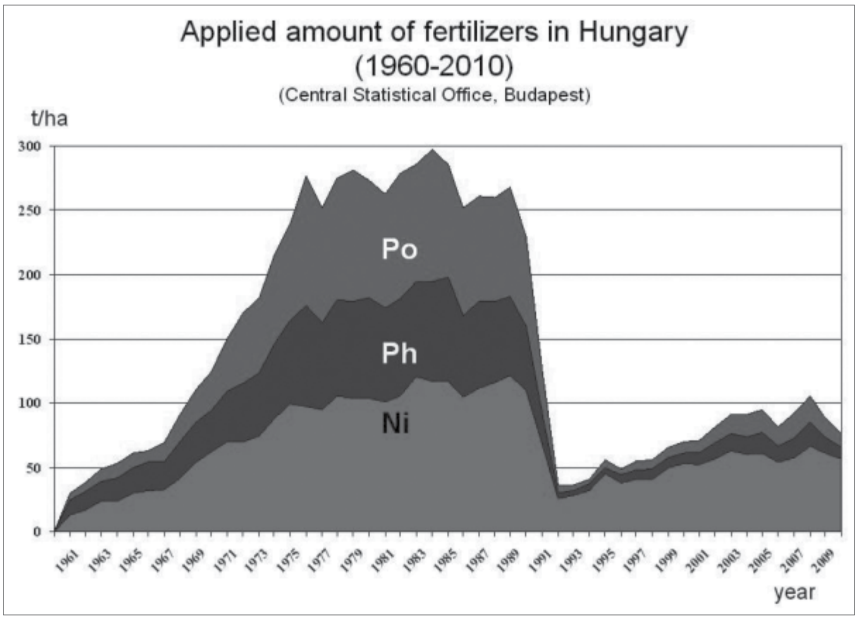


Table 1. Identification of Lr 34 tested in Martonvásár wheat genebank collection

Origin	Total number of genotypes	No. of genotypes with Lr34
Martonvásár	129	35 (27.1%)
Other	97	29 (29.9%)
Total	226	64 (28.3%)

Figure 2. Recurrent parent genome (RPG) recovery using marker-assisted backcrossing (MABC) and traditional backcrossing (Frisch *et al*., 2000)

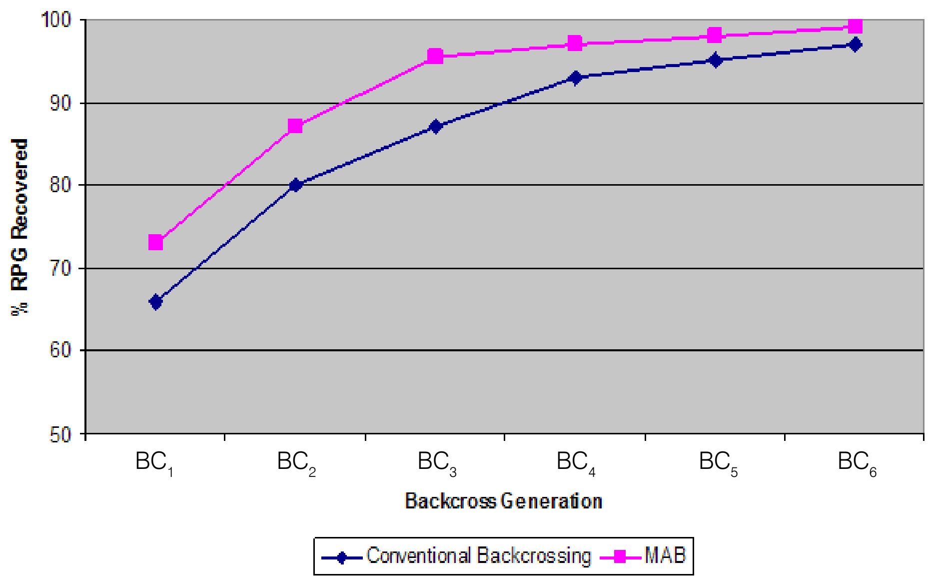
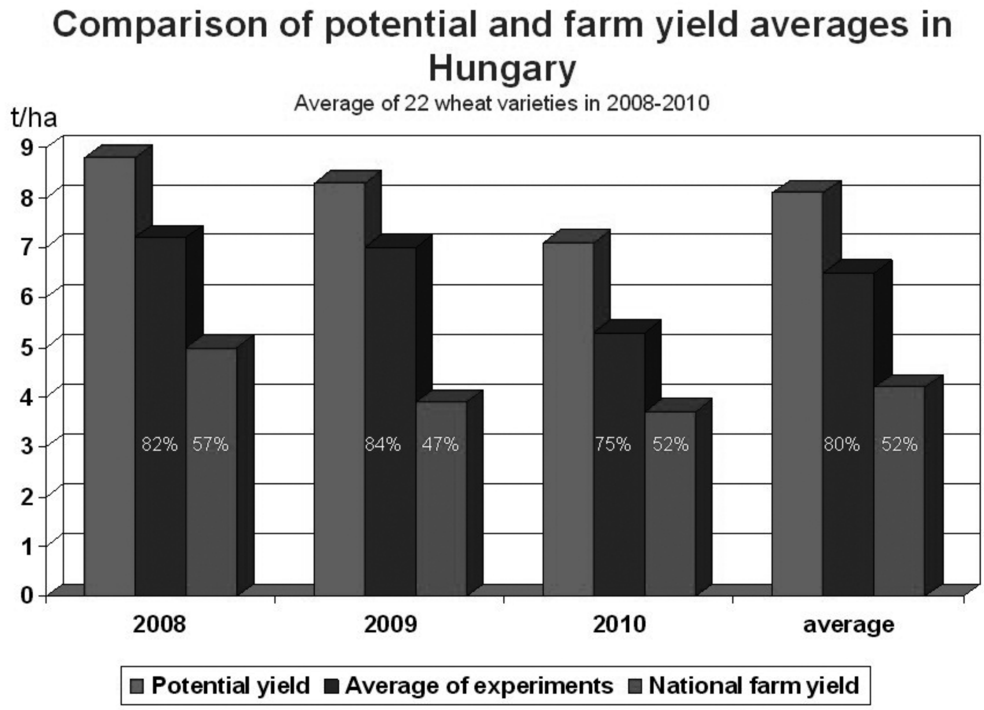


Figure 3. Comparison of potential and farm yield averages in Hungary



References

Balfourier, F., Roussel, V., Strelchenko, P., Exbrayat-Winson, F., Sourdille, P., Boutet, G., Koenig, J., Ravel, C., Mitrofanova, O., Beckert, M., and Charmet, G., 2007. A worldwide bread wheat core collection arrayed in a 384-well plate. Theor Appl Genet, 114, 1265- 1275.

Bedő, Z., Balla, L., Szunics, L., Láng, L., and Kramarikné Kissimon, J., 1993. Agronomical properties of the Martonvasar wheat varieties with 1B/1R translocations. Növénytermelés, 42, 391-398.

Bedő, Z., Karsai, I., Balla, L., and Barnabás, B., 1988. Some possibilities of efficient haploid production in wheat. In: Miller TE, Koebner RMD: Proceeding of the 7th International Wheat Genetic Symposium. Cambridge, UK, 1043-1046.

Bedő, Z., Láng L., Veisz, O., and Vida, Gy., 2005. Breeding of winter wheat (*Triticum aestivum* L.) for different adaptation types in multifunctional agricultural production. Turk. J. Agric. For., 29, 151-156.

Bedő Z., 2008. A Pannon minőségű búza nemesítése és termesztése. Agroinform kiadó, Budapest. p. 107.

Bespalova, L., 1996. Wheat breeding in Krasnodar Research Institute of Agriculture, Scientific Works. Anniversary Issue, devoted to 95th year form the birth of the academician P.P. Lukyaneneko, Krasnodar, pp. 396.

Borojevic, S., 1990. Genetic improvement in wheat yield potential. Savremena Poljop. Novi Sad, 38, 1-2., 25-47.

Breseghello, F., and Sorrells, M., 2006. Association analysis as a strategy for improvement of quantitative traits in plants. Crop Science, 46, 1323-1330.

Butow, B.J., Gale, K.R., Ikea, J., Juhász, A., Bedő, Z., Tamás, L., and Gianibelli, M.C., 2004. Dissemination of the highly expressed Bx7 glutenin subunit (Glu–B1 allele) in wheat as revealed by novel PCR markers and RP-HPLC. Theor. Appl. Genet., 109, 1525-1535.

Cloutier, S., and Lukow, O.M., 1998. Cloning and expression of a rare LMW glutenin. Proc. of the 9th International Wheat Genetic Symp. Saskatoon, 3:2-4.

DePauw, R.M., Clarke, J.M., McCaig, T.N., and Townley-Smith, T.F., 1998. Opportunities for the improvement of Western Canadian wheat protein concentration, grain yield and quality through plant breeding. in: Fowler, D.B., Geddes, W.E., Johnston, A.M., Preston, K.R., Wheat protein production and marketing. Proc. Wheat Protein Symp., Saskatoon, Saskatchewan, Canada, 75-93.

Dorofeev, V.F., and Udachin, R.A., 1987. Wheats of the world. Agropromizdat, Leningrad, pp. 560.

Dunwell, J. M., 2008. Transgenic wheat, barley and oats: future prospects. In: Jones, H.D., Shewry, P. R., Transgenic wheat, barley and Oats, production and characterization protocols, Springer Protocols, Methods in Molecular Biology, Humana Press, Totowa, NJ, 333-346.

Dyck, P.L., 1994. Genetics of resistance to leaf rust and stem rust on wheat. Annual Wheat Newsletter, 40, 63-64.

Fischer, R.A., and Edmeades, G.O., 2010. Breeding and cereal yield progress. Crop Science, 50, 85-98.

Frisch, M., Bohn, M., and Melchinger, A.E., 2000. PLABSIM: Software for simulation of marker-assisted backcrossing. J. Hered., 91, 86-87.

Jakubziner, M.M., 1962. Wheat species and varieties as resources in plant breeding. Proc. Of the Symposium on genetics and wheat breeding, Martonvásár, 405-422.

Javornik, B., Sinkovic, T., Vapa L., Koebner R. M. D., and Rogers, W. J., 1991. A comparison of methods for identifying and surveying the presence of 1BL. 1RS translocations in bread wheat. Euphytica, 54, 45-53.

Juhász, A., Larroque, O.R., Tamás, L., Hsam, S.L.K., Zeller, F.J., Békés, F., Bedő, Z., 2003. Bánkúti 1201 - an old Hungarian wheat variety with special storage protein composition. Theor Appl Genet, 107: 697-704.

Lelley, J., 1967. Variety policy and the Hungarian wheat varieties. Mezőgazdasági Kiadó, Budapest, pp. 127.

Litvinenko, M.A., 1998. Breeding intensive winter bread wheat varieties in Ukraine. Euphytica, 100: 7-14.

Litvinenko, M., Lyfenko, S., Poperelya, F., Babajants, L., and Palamatchuk, A., 2001. Ukrainien Wheat Pool. In: Bonjean, A.P., Angus, W.J., (Eds.), The world wheat book; a history of wheat breeding. Lavoisier Publishing, Paris, 351- 375.

Lukyanenko, P.P., 1966. Metodi i rezultati szelekcii ozimoj psenici. in: Trudi Krasznodarszkogo NISzH. Krasznodarszkoje knizsnoje izdatelsztvo, Krasznodar, 2, 26-49.

Lyfenko, S.F., 1987. Semi-dwarf wheat varieties. Urozshay, Kiev, pp. 285.

Marchylo, B.A., Lukow, O.M., and Kruger, J.E., 1992. Quantitative variation in high molecular weight glutenin subunit 7 in some Canadian wheat. Journal of Cereal Science, 15, 29-37.

Molnár-Láng, M., Linc, G., Sutka, J., 1996. Transfer of the recessive crossability allele *kr1* from Chinese Spring into the winter wheat variety Martonvásári 9. Euphytica 90:301–305.

Nava, I.C., Rouse, M.M., Chao, S., Jin, Y. and Anderson, J.A., 2012. Genetics and mapping of stem rust resistance in winter wheat cv. MV Zelma. In: Proc. Borlaug Global Rust Initiative, Technical Workshop, ed.: McIntosh R., Beijing, China. pp. 141.

Rabinovich, S.V., 1998. Importance of wheat-rye translocations for breeding modern cultivars of *Triticum aestivum* L. . Euphytica, 100:323-340.

Rakszegi, M., Pastori, G., Jones, H.D., Békés, F., Butow, B., Láng, L., Bedő, Z., and Shewry, P.R., 2008. Technological quality of field grown transgenic lines of commercial wheat cultivars expressing the 1Ax1 HMW glutenin subunit gene. Journal of Cereal Science, 47, 310- 321.

Saulescu, N.N., Ittu, G., and Giura, A., 1988. Identification of height reducing genes in several semi-dwarf winter wheat cultivars. Probl. Genet. Theor. Appl., 20, (4), 227-237.

Saulescu, N.N., Ittu, G., Balota, M., Ittu, M., and Mustatea, P., 1998. Breeding wheat for lodging resistance, earliness and tolerance to abiotic stresses. In: Braun, H.J., *et al*., (Eds.), Wheat: prospects for global improvement. Kluwer Academic Publishers, Netherlands, 181-188.

Singh, R. P., Kinyua, M. G., Wanyera, R., Njau, P., Jin, Y., and Huerta-Espino, J., 2007. Spread of a highly virulent race of *Puccinia graminis tritici* in Eastern Africa. in Buck, H. T., Nisi, J. E., Salomón, N., Wheat production in stressed environments, Proc. of the 7th Int. Wheat Conf. 2005, Mar del Plata, Argentina, Springer, Dordrecht, 51-57.

Strebeyko, P., 1976. Biologia pszenicy. Warsaw,PWN, 14-16.

Szunics, L., Láng, L., Balla, L., and Bedő, Z., 1985. Búzafajtáink szem-szalma aránya. in:Bajai-Koltay (eds.): Búzatermesztési kísérletek 1970-1980. Akadémiai Kiadó, Budapest, 112-118.

Vassiltchouk, N.S., 1999. Methods of breeding the spring durum wheat (*T. Durum Desf.*) for productivity and grain quality in Low Volga Region. Thesis for Doctor’s Degree, Res. Inst. of Agriculture of South-East Saratov, pp. 78.

Vavilov, N.I., 1935. Scientific basis of wheat breeding. in: Theoretical basis of plant breeding, Vol 2. Applied breeding of cereal and forage crops, Selskhozgiz, Moscow, Leningrad, pp. 224.

Veisz, O., Braun, H.J., and Bedő, Z., 2001. Plant damage after freezing, and the frost resistance of varieties from the facultative and winter wheat observation nurseries. Euphytica, 119, 179-183.

Veisz, O., Harnos, N., Szunics, L., and Tischner, T., 1996. Overwintering of winter cereals in Hungary in the case of global warming. Euphytica, 92, 249-253.

Vida, Gy., Gál, M., Uhrin, A., Veisz, O., Syed, N.H., Flavell, A.J., Wang, Z., and Bedő, Z., 2009. Molecular markers for the identification of resistance genes and marker-assisted selection in breeding wheat for leaf rust resistance. Euphytica, 170, 67-76.

Zhukovsky, P.M., 1957. Wheat in the USSR. State Publishing House of Agricultural Literature, Moscow, Leningrad, pp. 632.