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ORIGINAL PAPER

Bulgarian variety samples as source material for winter wheat breeding in the conditions of forest-steppe of Ukraine

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Abstract

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Search and creation of breeding sources is of great importance to expand genetic diversity of varieties. The studying source material as basis of breeding determines its efficiency. Under conditions of global climate change, breeders need sources of valuable traits with genes controlling the resistance of plants to abiotic and biotic factors of the environment. Based on mutual agreement on cooperation in winter wheat breeding between Myronivka and Bulgarian breeders, in 1987-2013 there have been studied Bulgarian samples in order to create new source material. Contrast weather conditions in the years of the research well showed the instability of climatic conditions in the zone of Right-bank Forest-Steppe of Ukraine, which made it possible to obtain objective results. In the conditions of the Ukrainian Forest-Steppe, features of complex valuable traits in 1470 breeding samples from the Institute for Wheat and Sunflower "Dobroudja" (hereinafter Dobrudzha Agricultural Institute) were defined. The sources of productivity, high winter hardiness, short stem, and group resistance to diseases have been identified to use in breeding programs for creation of bread winter wheat varieties and intermediate forms. In samples of Bulgarian breeding such traits as cropping season duration, plant height, lodging resistance were revealed to be the most stable, whereas brown rust resistance, frost resistance, grain yield and flour strength were the most variable ones. It was shown that in 72.1% of the cases, the relationship between these seven traits was weak, which allowed to combine the useful traits with high level of their performance in the conditions of the Ukrainian Forest-Steppe. Correlation analysis of agronomic traits confirmed the availability of genotypes combining high grain yield, winter hardiness, earliness, grain-size with good baking quality. There were identified the sources 2579-30-19, 853/ 7-44-38, Rusalka, Pliska, Milena, Lilia, 836/87-2,

M-1022-6567, 6687-12, 1769-64, DM-62-44 combining the sufficient level of productivity and other valuable traits. When involving these sources in crosses and further selecting, the new varieties Myrych, Myrliena, Berehynia myronivska, Hospodynia myronivska, MIP Vyshyvanka and MIP Kniazhna have been developed. They are resulted from the successful international cooperation of Ukrainian and Bulgarian wheat breeders.

Key words: Bulgarian sample, Productivity, Variety, Winter wheat

Introduction

In order to strengthen global food security, taking into account the challenges posed by climate change, there is a growing need for the expansion of existing genetic diversity and the creation of stress-tolerant varieties with high genetic yield potential (Djanaguiraman & Prasad, 2014; Reynolds et al., 2015; Valluru et al., 2014). In advanced countries, yield increase by 90-95 % depends on the genetic and breeding improvement of varieties and hybrids, and only by 5-10 % on the improvement of agrotechnologies (Dragavtsev et al., 2011). The role of genotype in increasing and stabilizing yields is constantly rising, and the contribution of the variety is 30-50 % (Rybas', 2016). By 2020, the share of yield increase resulted from the new generation of varieties will be about 70-80 % or 2-3 times higher than the level achieved now (Zakharchuk, 2009).

Creating new varieties to a large extent depends on the source material as the first and very important stage of the breeding process. With the intensification of agricultural production around the world, a tendency towards reduction in the genetic diversity of commercial varieties of common wheat is developing (Porceddu, 1988). In large areas there dominated limited number of wheat varieties that increases genetic uniformity and leads to loss of germplasm of the crop. Such process leads to decrease in adaptive potential of the species under different conditions of the environment (Altukhov, 2003). According to FAO experts, about 75 % of the global genetic diversity of crops has been lost throughout the twentieth century. In the United States, for example, 97 % of the varieties registered in the old state registers have already been lost, in Germany 90 % of the historical diversity of cultivated plants, in Italy 70 % of the old local varieties adapted to the growing environment have disappeared forever (Tsygankov, 2009). The threat to sustainable agricultural development is not so much in reduction of genetic diversity if it is viewed as the total number of alleles present in the gene pool, but because of the loss of rare, valuable alleles and phenotypes with hidden effect which can only be as a result of the breeder's work (Dzyubenko, 2009). Thus, for breeding and genetic improvement of winter wheat the systematic use of its global diversity is crucial. Wide genetic diversity of varieties enriches the crop, makes its production more stable and is the basis of the adaptive potential of winter wheat.

For the purposeful and effective use of the source material in breeding winter wheat for conditions of the Forest-Steppe of Ukraine at the V. M. Remeslo Myronivka Institute of Wheat broad methodological study of the global diversity of variety samples of this crop is carried out. Sources of valuable traits identified are included in breeding programs of the Cereal Crop Breeding Department. In April 1986, bilateral agreement was signed on cooperation in winter wheat breeding between Myronivka Research Institute of Breeding and Seed Production of Wheat and the Institute for Wheat and Sunflower "Dobroudja" (General Toshevo, PRB) (Chebakov, 2012). The program of cooperation was developed and detailed for the purpose of creating new high-yielding varieties of winter wheat with a yield potential of 9-10 t/ha, high-resistance against diseases, lodging and stress factors, with high baking quality. The main result of the successful international cooperation of Ukrainian and Bulgarian breeders has been the creation of winter wheat varieties Myrych, Myrliena, Berehynia myronivska, Hospodynia Myronivska, MIP Vyshyvanka and MIP Kniazhna.

Materials and methods

The work was aimed to complex study of initial material of common (bread) winter wheat presented by 1470 variety samples bred at the Institute for Wheat and Sunflower "Dobroudja" (since 2001 it is Dobrudzha Agricultural Institute (DAI), the identification of sources of agronomic traits for further breeding activity and creation based on their participation high-yielding, adapted to conditions of Forest-Steppe varieties with high grain quality indices. The experimental part of the work was carried out in 1987-2013 in breeding crop rotations of the Laboratory of International Breeding Researches of Winter Wheat (since 2004 it is the Laboratory of Ecological Breeding) of the V. M. Remeslo Myronivka Institute of Wheat of the National Academy of Agrarian Sciences of Ukraine (MIP). Contrast weather conditions in the years of the research well showed the instability of climatic conditions in the zone of Right-bank Forest-Steppe of Ukraine, which made it possible to obtain objective results. Methods – field (planning and carrying out field experiments); accounting and weight – accounting wheat grain yield and its components; physical and biochemical – assessment of grain quality indices; calculation and comparative – assessment of economic efficiency; methods of mathematical statistics – for objective quantification of experimental data.

Results and discussion

The research of the source material was carried out in field and laboratory conditions in comparison with the variety-standard according to the main parameters. For the period 1987-2013, 522 samples were comprehensively studied

in various crop rotation of breeding process with measuring yield.

Winter hardiness. During the years of the research most of the samples (54.9 %) had winter hardiness score seven or eight points. The great variability of winter hardiness confirmed with the high (24.3 %) coefficient of variation during the period of the research is explained both by genetic and environmental factors to be consequence of the reaction of a certain genotype to specific conditions of the environment. In the period of the research, 32% of the cases (nine years) in winter periods adverse weather conditions were marked which resulted in the death of the material (partial or full) and made it possible to objectively assess the level of winter hardiness and frost resistance of the Bulgarian samples.

Significant direct correlation (r = 0.44, at probability 5 % level of significance) between winter hardiness (overwintering in score) and yield was noted. The analysis of the correlations between winter hardiness and cropping season duration, plant height and resistance to Septoria leaf blotch shows weak degree of correlation of these traits (r = -0.26, r = 0.12 and r = 0.21, respectively).

During the research, we have identified samples 6687-12, 836 / 87-2, 759-1, 853 / 87-44-38, 2579-30-19, M-1022-6567, 854 / 87-2, 6382-6, DM-27-15, Milena, DM-62-44, DM-61-67, 1919-50, 226/86-152, 498/88-77, 83/88-99, 102-72, 1769-64, 148-133-21, 4851-67 which combined sufficient level of winter hardiness and productivity of plants, other valuable characters. All these samples have increased tillering capacity and regenerative ability combined with the rapid spring regrowth, as well as high level of winter hardiness, which was confirmed in the years with extreme overwintering conditions.

Cropping season duration varied depending on the conditions of the year – the difference was of 223 to 256 days (Figure 1). It was the shortest in 2010 (on average 220 days), and the longest in 1988 (251 days with a range of 249 to 259 days).

Heading date for the years of the research changed from May 11 to June 4. Hydrothermal regimes during the years of the study significantly influenced not only on the onset of heading phase, but also on the reaction of various genotypes, resulting in shift for some variety samples from one group of ripeness to another.

The analysis of variation coefficients for the entire period of studies showed a low degree of variation of the trait “cropping season duration”, although the differences between individual samples were significant: the minimum value of the symptom was 217 days, the maximum one was 259. Correlation analysis allowed to detect a reliable negative relationship of the average strength between duration of the period emergence–heading and yield (r = -0.39), 1000 kernel weight grains (r = -0.33).

This indicates the possibility of selecting early-ripening and simultaneously high-performance forms. Among the sources of earliness the samples with, short-

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stem, lodging resistance and high grain quality indices Rusalka, 3324-1, 97 / 58-1, 8601-132, 95 / 251-1-1, 6000-1 (resistant to brown rust), 6687-12 (with increased winter hardiness), 244 / 92-114 (resistant to powdery mildew) are of great interest for breeders.

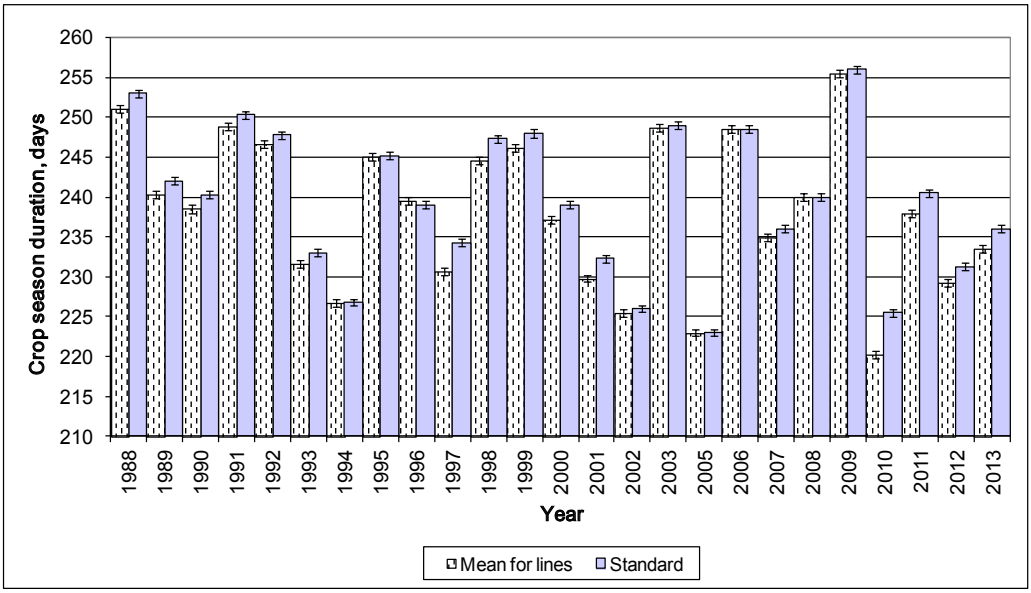

Figure 1. Cropping season duration of Bulgarian samples of winter wheat.

Plant height and lodging resistance. Hydrothermal regimes significantly influenced on plant height of Bulgarian samples, resulting in that about 95 % of samples came from one group in height to the other. Among the varieties studied, group of short-stemmed ones with height of 80-100 cm represented 48 % and middle-stemmed with height of 101-120 cm was 32 %. The analysis of the coefficients of variation showed an average degree of variation of "plant height" and "lodging resistance" (13.6 and 13.7 %, respectively), although the differences between individual samples were significant: the minimum value of the trait being 55 cm (in 1999) with a score of one (1998) and the maximum value 130 cm (1998) and score of nine (in several years). The character of variation of the traits indicates the possibility of breeding short-stemmed plants as for the shortening of the total plant length, as well as high lodging resistance. The phenotypic correlation coefficient between plant height and grain yield was positive low (r = 0.17), that is, the reliable effect of stem height on yield was not established. This indicates that high-yielding forms can be simultaneously short-stemmed. The samples 2579-30-19, 63-55, 6687-12, 301-44-55, 268-50-1, Milena, 97/58-1, 3324-1, 76-24-58-6, 8601-132, 2514-114 combined short-stem and high lodging resistance. These

Bulgarian samples are valuable source in winter wheat breeding for lodging in the conditions of the Forest-Steppe of Ukraine.

Disease resistance. According to the correlation analysis, the average mean of brown rust (*Puccinia recondita*) damage was substantially close to the standard deviation: 28.0 and 21.9 %, respectively. This indicates a significant dependence of the expression of the trait on growing conditions (hydrothermal regime of the spring and summer period contributing to the epiphytoties and, probably, difference of the pathogen population from the Bulgarian population) and various genetic level of brown rust resistance in the samples. Among Bulgarian variety samples (BVS) being the best in the complex of traits there were resistant (11.0 %), middle-resistant (29.1 %) and susceptible (35.5 %) ones (Figure 2).

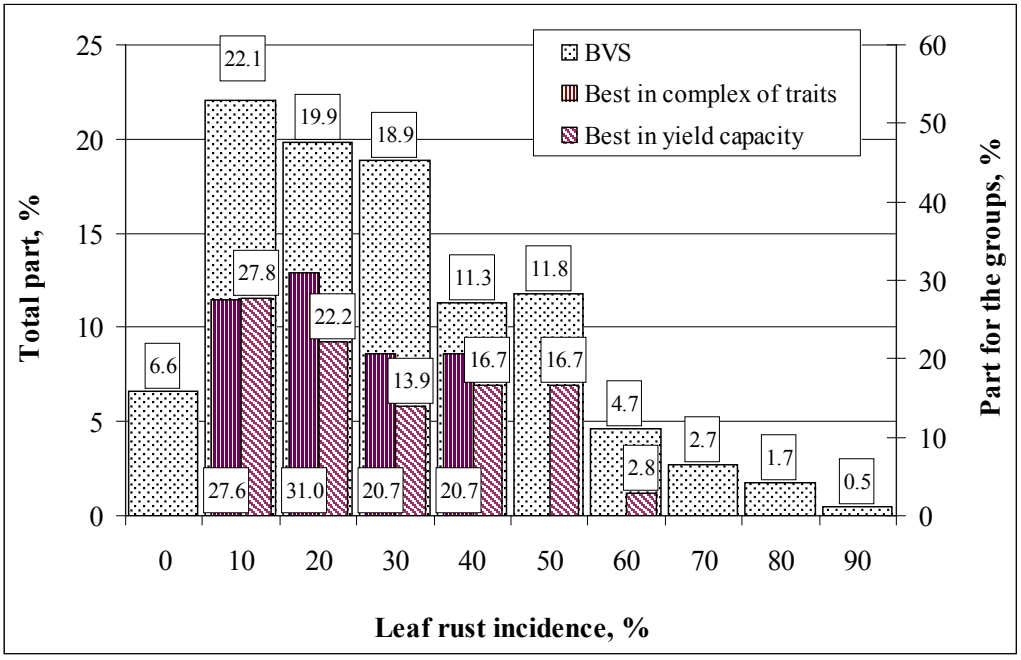

Figure 2. Distribution of winter wheat Bulgarian samples for brown rust resistance, averaged over 1990–2013.

During the research period, the group of immune, high-resistant and resistant samples prevailed (69.7 %), and the group with the maximum damage (60-90 %) was the least 5.7 %. Even in years with strong epiphytoties of brown rust, the proportion of resistant material was no less than 30 %, excluding 1998 (11 %). In the case of powdery mildew (*Erysiphe graminis*) and *Septoria trtici* leaf blotch, the most of the variety samples (57.0 % and 58.3 %, respectively) belonged to the middle susceptible ones, with a score of five to six, As for powdery mildew, the

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group of resistant samples prevailed – 30.0 %, for leaf blotch it was only 20.5 %. The most valuable for breeders are The samples that combine group resistance to three diseases with a set of agronomic traits: winter hardiness, large seed, productivity, good grain quality 2579-30-19, 836 / 87-2, DM-62-77, 759-1, 1919-50 as well as yielding capacity, large seed and high grain quality 97/58-1, MT-17131-87, 71/90-1097, 2514-114 are of great interest for wheat breeding.

Grain quality indices. By the level of grain quality characteristics Bulgarian samples exceeded the standard variety for protein content (14.8 %, in the standard 11.1 %) and gluten content (26.8 % and 26.4 %, respectively). The conditions of the year and the genotype influenced in different ways on the level of grain quality indices. The variability of gluten content (Cv = 13.6 %), protein content (Cv = 14.2 %) and bread volume (Cv = 17.6 %) were moderate (table 1).

Table 1. Expression level and statistical parameters of grain quality indices of winter wheat Bulgarian samples, average for 1987-2013.

Statistical parameters	Protein content (%)	Sedimentation index (ml)	Gluten content (%)	Flour strength (A.U.)	Bread volume (cm^3)
$\bar{x}$	14.8	43.9	26.8	174.9	623.7
max	16.9	82.0	38.0	444.0	900.0
min	9.2	18.0	17.1	19.0	360.0
R	7.7	64.0	20.9	425.0	540.0
σ	2.10	11.15	3.65	98.70	109.60
C_V, %	14.2	25.4	13.6	56.4	17.6
$\bar{x}$-σ	12.7	32.8	23.2	76.2	514.1
$\bar{x}$+σ	17.0	55.1	30.4	273.6	733.3
$LSD_{0.05}$	1.19	6.83	2.44	33.87	52.96

The degree of variation of most grain quality characteristics in the samples makes it possible to effectively evaluate the genotypes according to the level of these indices. Sedimentation index (Cv = 32.8%) and flour strength (Cv = 56.4%) varied significantly. The samples 1769-64, 2514-114, 2579-30-19, Milena, M-1022-6567, Lilia, MT-17131-87, MT-18040-30, 836/87-2, 97 / 58-1, 49/94-168 were characterized with best quality indices.

Yield. The highest grain yield of Bulgarian samples was obtained in favorable 2009 (9.1 t/ha) and 1998 (8.2 t/ha). The minimum yield of the variety samples was formed under insufficient weather conditions in 1999 (3.3 t/ha), 2000 (4.2 t/ha), 1991 and 2002 (4.3 t/ha), 1992 and 2006 (by 4, 1 t/ha) (figure 3). The middle variation level for the 1000 kernel weight was revealed. The differences between

individual samples were significant: the minimum value was 17.4 g (1989) and 23.5 g (1991), the maximum 61.0 g (1993), 58.8 g (1996), 57.0 g (1998). The range of variability was maximum in 1990 (30.7-52.4 g) and 1993 (40.0-61.1 g), the minimum in 2006. The samples 2514-114, 2579-30-19, Milena, 853/87-44-38, 836/87-2, 104/87-76-21, 809/87-5-34, 97/58-1 were the best ones for grain size and grain filling which stably formed 1000 kernel weight over 40 g.

In 72.1% of cases, the correlation for the most traits was insufficient, thus allowing to predict the effectiveness of selection for a combination of useful traits with high level of their manifestation in the conditions of the Forest-Steppe of Ukraine. The analysis of correlation of the valuable traits confirms the presence of genotypes combining high grain yield with sufficient level of winter hardiness (score of overwintering, r = 0.44), grain size (r = 0.43), earliness (r = -0.39), good baking quality (flour strength, r = 0.54).

For the period of the research (1987-2013), there have been identified the best variety samples of Bulgarian breeding with a complex of valuable agronomic traits which were involved in programs of crossing and used as parental forms in hybridization to expand the genetic basis and create new source material and bread winter wheat varieties (figure 4). It is known that the increase or decrease of the main polygenic character at genetic level leads to changes in other characteristics associated with it.

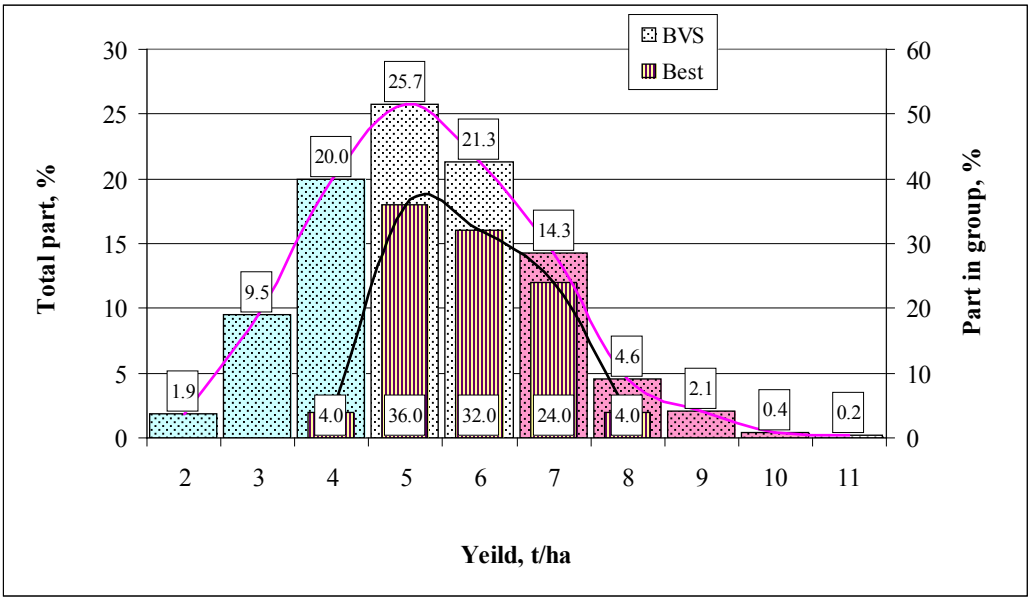

Figure 3. Grain yield of winter wheat Bulgarian samples.

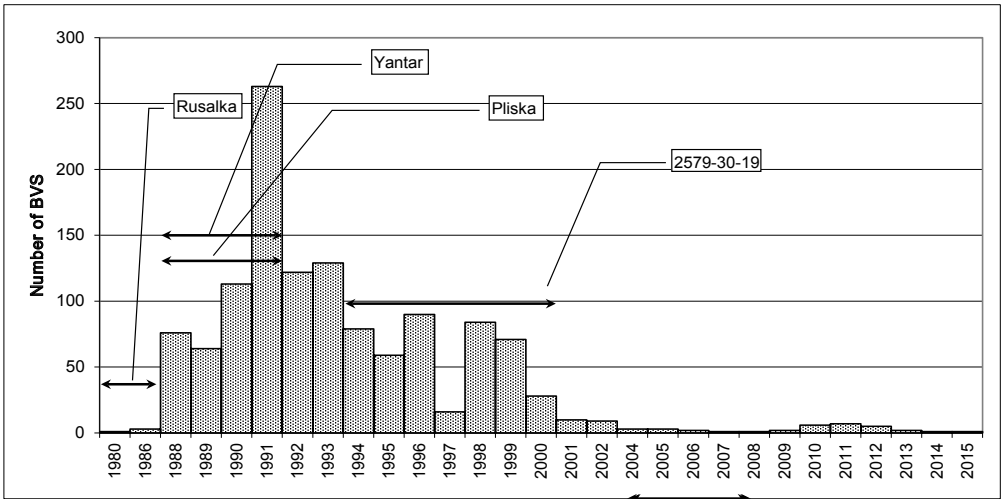

Figure 4. Number of winter wheat Bulgarian samples studied at the V. M. Remeslo Myronivka Institute of Wheat during 1988–2013
* Number of winter wheat Bulgarian samples being parents of Myronivka varieties

The average long-term values of agronomic traits of parent components should be in the limits of the average population plus the standard deviation. Such forms have an adequate response to sharp changes in environmental factors that trigger compensatory programs-answers. All the samples selected for a set of features are valuable source material for breeding in the MIP activity zone. By single crossing, intermediate lines were created which were later used as parent components, or complex (triple) crosses were carried out to create new varieties. Formative process in hybrid combinations is prolonged and requires more time and severe discarding at grain evaluation.

The analysis of manifestation level of 13 valuable traits (average value over years of the research) made it possible to identify only two samples (853/87-44-38 and 2579-30-19) possessing this level within $\bar{x}\pm\sigma$ for 12 traits excepting plant height. But according to the level of plant height these samples get into range of optimal stem length for samples of Bulgarian breeding under conditions of the Forest-Steppe of Ukraine (85-105 cm) and are lodging resistant.

The ability to form yield due to high grain weight per the main spike and grain size, multiflorous condition and high grain number per spike, as well as to wide assimilation surface, stem break resistance of the sample 2579-30-19 were stably inherited in its progenies. Due to the correct choice of components of single crossing (adapted productive line of local breeding and the sample 2579-30-19), a new of winter wheat variety Hospodynia myronivska has been created through purposeful

systematic selections.

With the participation of Bulgarian samples, the line Erythrospermum 50137 with a high breeding value has been created, which later became the founder of new varieties. Using parental forms that have high values for a set of agronomic traits allowed combining the sufficient under conditions of the Ukrainian Forest-Steppe winter-hardiness, the required cropping season duration, optimal for the growing area plant height, lodging resistance and resistance to group of diseases with high yield and grain quality indices. The winter wheat varieties Myrych, Myrliena, Berehynia myronivska, Hospodynia myronivska, MIP Vyshyvanka and MIP Kniazhna created are the result of the successful international cooperation of Ukrainian (MIP) and Bulgarian (DZI) breeders (table 2).

Table 2. Varieties bred at the V. M. Remeslo Myronivka Institute of Wheat when involving Bulgarian variety samples

Variety	BVS parents	Testing period at Myronivka	Variety release year	Registration year
Myrych	Yantar	1987–1991	1994	1999
Myrliena	Rusalka	1980–1986	2006	2009
	Pliska	1987–1991		
Berehynia myronivska	Rusalka	1980–1986	2012	2016
	Pliska	1987–1991		
	Yantar	1987–1991		
Hospodynia myronivska	2579-30-19	1994–2000	2013	2017
	Rusalka	1980–1986		
MIP Vyshyvanka	Rusalka	1980–1986	2015	2017
	Pliska	1987–1991		
MIP Kniazhna	Rusalka	1980–1986	2015	2017
	Pliska	1987–1991		

Conclusion

The results of the research (1987-2013) make it possible to state that among the 1470 winter wheat samples of Bulgarian breeding studied no forms suitable for direct (by introduction) use under conditions of Ukrainian Forest-Steppe were found.

Various levels of expression and variability of agronomic traits in Bulgarian samples have been found that testifies to the possibility to achieve a sufficiently high intensity of formative processes by involving them in hybridization with varieties and lines of local breeding. Among the diversity of hybrid genotypes obtained, by

subsequent selections the forms have been obtained that combine the optimal level of valuable traits, so it confirms the expediency of using samples of Bulgarian breeding as the source material.

It has been proved that within the samples of Bulgarian breeding such agronomic traits as cropping season duration (Cv = 3.4%), plant height (Cv = 13.6%), and lodging resistance (Cv = 13.7%) were the most stable, whereas brown rust resistance (Cv = 73.6%), frost resistance (Cv = 52.8%), yielding capacity (Cv = 36.1%) and flour strength (Cv = 56.4%) were the most variable ones. The low level of variation of quantitative traits increases the efficiency of selecting genotypes with sufficient level of them, the mean and significant level does not exclude the possibility to select genotypes with the value of each of a number of valuable traits close to the adaptive norm for specific growing conditions.

It was shown that in 72.1% of cases, the correlation for the most traits was low, which allows to predict the effectiveness of selection for a combination of useful traits with high level of their manifestation in the conditions of the Forest-Steppe of Ukraine. Correlation analysis of main agronomic traits has confirmed the availability of genotypes combining high grain yield and winter hardiness (r = 0.44), earliness (r = -0.39), grain-size (r = 0.43) with good baking quality (flour strength, r = 0.54).

There were identified the sources 2579-30-19, 853/ 7-44-38, Rusalka, Pliska, Milena, Lilia, 836/87-2, M-1022-6567, 6687-12, 1769-64, DM-62-44 combining the sufficient level of productivity and other valuable traits.

Thus, an international coordinated approach to exchange of knowledge and materials between breeders from different countries and the identification of the priority areas of future research can increase the efficiency of research in breeding.

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