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BREEDING OF SPELT WHEAT (*Triticum spelta* L.) FOR PRODUCTIVITY AND GRAIN QUALITY

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Abstract

Spelt (*Triticum spelta* L.) is an ancient species of wheat demand for which is currently increasing. Along with positive characteristics of spelt (high protein, gluten and amino acids content, high adaptive potential, presence of a powerful stem and high resistance to lodging) it is significantly inferior to soft wheat *T. aestivum* L. in terms of yield capacity. However, new perspective genotypes with improved quantitative traits can be obtained from crosses of spelt and soft wheat due to introgression of genetic material of *T. aestivum* into *T. spelta* genome. In present research in result of hybridization of spelt wheat and soft wheat we obtained new forms which differ from each other in terms of morphobiological and economically valuable traits. The research aimed to create new initial material of spelt with high quality of grain based on hybridization of *Triticum aestivum* and *T. spelta* and its introduction to the breeding scheme for creating high productive varieties of the crop. Samples of spelt wheat obtained by the method of remote hybridization followed by multiple individual selection. Spelt samples of local breeding from foothill regions of the Carpathians and regionalized varieties of winter wheat Favoritka, Kharus, Panna, Ermak, Podolianka, Kryzhynka, Farandol, Kopilovchanka, Krasnodarskaia 99 were used as initial breeding material. Derived F_1 hybrids were self-pollinated or back-crosses with parental forms. Hybrid progenies F_{2-5} were analyzed in terms of morphobiological and economically valuable traits (plant height, shape of the bush, wax coating on plants, pubescence on the stem and spike, length, color and awnedness of the spike, number of spikelets in the spike, density of the spike, threshing of grain, grain shape and color, weight of the grain from the main spike, number of productive stems per plant, 1000-grain weight, gluten and protein content, grain hardness, productivity). In fifth generation (F_5) when segregation was no longer observed, considering productivity and quality of previous years, 18 best samples of spelt wheat were selected. Their field testing was conducted during 2012-2018 (F_{5-11}) (a research field of Uman National University of Horticulture, right-bank Forrest-steppe of Ukraine, Cherkassy region). Gluten and protein contents were determined by infrared spectroscopy (Laboratory of genetics, breeding and seed production, a device Infratec^{TM} Nova, FOSS Analytical, Sweden**).** Biometric traits **(**plant height, ear length, number of grains per ear, grain weight from head ear) were determined on 50 plants selected from each plot in two non-adjoin repetitions. Grain threshing was performed, and yield capacity was determined. From crossing, the collection of spelt initial material which include more than 200 samples was created. Obtained forms were divided into four groups according to plant height: semi-dwarf, low-growing, medium-growing and high-growing. In each group the best samples were selected which were analyzed for grain quality, yield and productivity structure. A possibility was proved of breeding improvement of spelt based on interspecific hybridization with soft wheat. It was established that eight samples significantly exceeded standard for yields. In the same time samples Nos. 76, 155, 1695 и 1725 had improved grain threshing (80-90 %), samples Nos. 76 and 1817 were characterized by high quality, in particular, 25.2 and 22.0 % protein content, respectively, and 52.1 and 44.7 % gluten level. Samples Nos. 40 and 13 were the best in terms of gluten and protein content with 30.1 and 27.2 % for protein, and 63.2 and 56.5 % for gluten, respectively. As a result of the study, spelt wheat forms were selected which possess several valuable traits, i.e. the sample No. 124 is distinguished due to low plant height (92 cm) and high quality traits (1000-grain weigh of 53.8 g, protein content of 17.9 %, I group gluten level of 37.4 %), while the sample No. 155 shows high

productivity (5.36 t/ha) and an improved grain threshing out from the ear (92 %). A winter spelt variety Europe derived from spelt and soft wheat hybridization has been listed to State register of plants suitable for growing in Ukraine from 2015.

Keywords: spelt wheat, soft wheat, hybridization, yield capacity, grain threshing, protein content, gluten content

Spelt wheat (*Triticum spelta* L.) is one of the most ancient cultivated wheat species, which was known as early as the 7th-8th millennia BC. Spelt originates from Southeast Asia, from where it spread to North and Central Europe. The Asian spelt subspecies are most likely result from spontaneous hybridization of *T. turgidum* ssp. *dicoccon* and *Aegilops tauschii* ssp. *strangulata*, and later from the spelt the naked hexaploid species were derived, including *T. aestivum* L. Spelt wheat is identical to common wheat in genomic composition and chromosome structure of some genomes [1, 2].

Spelt wheat was grown in ancient times, but gradually it disappeared from crops because of low productivity. Currently, the demand for spelt is growing due to the high protein content in grains and the presence of a number of nutrients and amino acids not found in animal products [3-6]. In protein content spelt plants exceed *T. aestivum* by 8-10%, *T. sphaerococum* Persiv. by 3-8%, *T. petropavlovskyi* Udacz. et Migusch by 2-6% [7-10]. In tryptophan level, it surpasses soft wheat by 10-15%, hard wheat by 15-20%, and also spelt grain contains 16-20% more general gluten (prolamines and glutenins) than soft wheat. Moreover, spelt grain contains less gluten fraction than soft wheat, barley, and oats, which allows spelt to be used in dietary nutrition [11, 12].

Recent market offers to grain producers a small number of spelt varieties, and their diversity is limited mainly by local forms of folk selection. In this regard, spelt cannot compete with soft wheat [3, 13]. An urgent task of spelt breeding is to increase productivity while maintaining a high content of protein and grain fibrin [14, 15]. New hybrids with improved quality parameters can be obtained by crossing *T. spelta* with *T. aestivum*.

Many researchers engaged in the breeding improvement of spelt by crossing spelt with soft wheat indicate a positive effect from hybridization, in particular, a significant expansion of genetic diversity and the production of new transgressive forms [14, 16-18]. However, according to Fishing [19], such crosses are undesirable, since they lead to grain quality deterioration in spelt, and to difficult grain threshing and ear fragility in soft wheat.

Spelt wheat breeding in Ukraine focuses on increased productivity, reduced plant height, and improved grain threshing. Large-scale research was launched at the Yuriev Institute of Plant Industry NAAN (Kharkov), Remeslo Mironov Institute of Wheat NAAN (settlement Central, Kiev region), All-Ukrainian Research Institute of Breeding (VNIS) (Kiev) and Uman National University of Horticulture (UNUS) (Uman) [20-22]. Joint efforts of scientists from UNUS and VNIS created the first two varieties of winter spelt wheat, Zarya Ukraine and Europe, which are included in the State register of plants suitable for growing in Ukraine [23]. However, spelt is still a little widespread crop that requires breeding improvement.

In this work, as a result of hybridization of soft wheat with spelt, we obtained a number of new forms that differ from each other in morphobiological and economically valuable traits.

Our research aimed to initially improve grain quality of spelt wheat by hybridization of *Triticum aestivum* and *T. spelta* and then to use the obtained forms in breeding spelt wheat for high grain quality and yields.

Materials and methods. Spelt wheat samples derived from distant hybridization were subjected to multiple individual selection. The creation of the collection began in 2006 under the leadership of F.N. Parii. Spelt wheat samples of local selection from the foothill regions of the Carpathians and zoned varieties of winter soft wheat Favoritka, Kharus, Panna, Ermak, Podolyanka, Kryzhinka, Farandol, Kopilovchanka, Krasnodarskaya 99, etc. (about 60 varieties in total) were used as the initial material. Hybridization was carried out by manual castration of flowers on the maternal plants and their forced pollination with the paternal pollen. Upon reaching full maturity of the grain, the crop was harvested and evaluated.

Hybrid offspring F_{2-5} were analyzed for the following morphobiological and economically valuable traits: plant height, shape, waxy coating on plants and pubescence on stem and spike, spike length, color and awnedness, number of spikelets per spike, spike density, grain threshing, grain shape and color, grain weight per main spike, number of productive stems per plant, 1000-grain weight, protein and gluten content in grain, grain hardness and yield. In the fifth generation (F_5), when segregation was no longer observed, 18 best spelt wheat samples were selected for the research given the productivity and grain quality of previous years. The sample testing on the experimental field of the Uman National University of Horticulture (right-bank forest-steppe of Ukraine, Cherkasy region) lasted for 2012-2018 (F_{5-11}).

The content of grain fibrin and protein was determined by infrared spectroscopy (an Infratectm Nova instrument, FOSS Analytical, Sweden). The height of the plants was measured in the field before harvesting according to the method of the State Scientific and Technical Expertise of Varieties [24]. The samples were grouped by plant height as per Dorofeev et al. [25]. Test 10 m^2 plots were systematically distributed. The samples were grown in blocks with a crop density of 400,000 plants/ha. The experiment was repeated 5 times. Biometric indicators (plant height, spike length, number of grains per spike, grain weight per main spike) were determined for 50 plants selected from each plot in 2 distant replicates. Grain threshing was carried out and the yield was determined. The threshing ability was estimated as a percentage ratio of the amount of threshed grain to the total amount of grain from the site.

The data were statistically processed using Microsoft Excel 2010. When determining the means (M), their standard errors (±SEM) and the relative standard errors (experimental error, Sx, %) were calculated. The least significant difference ($LSD_{0.99}$ for the grain fibrin and protein content, $LSD_{0.95}$ for other indicators) and the coefficient of variation (Cv, %) were calculated as per Ermantraut and Gudz [26].

Results. The original plants of spelt wheat were high (more than 120 cm), had a long (20 cm), loose, narrow, fragile, hulled, awnless ear of white color without wax coating. An ear, when ripe, splits into separate segments with grain which is difficult to thresh due to thick coarse spikelet hulls. In the initial form, grain productivity was 4.15 t/ha, with 25% protein content, and 50-52% grain fibrin. The parental soft wheat varieties were semi-dwarf (Kopilovchanka, Panna, Ermak, Kharus) or with low stem height (Favoritka, Podolyanka, Krasnodarskaya 99, Kryzhinka, Farandol). All varieties are bare-grain, with optimal threshing ability, differing from each other in approbation traits (wax coating, pubescence of plants and spikes, plant, spike and grain color, shape, density and length of spike, size and shape of spikelet scales, plant

shape, awnedness-awnless, grain shape and size) and economically valuable traits (yield, grain fibrin and protein content).

The resulting F_1 hybrids were self-pollinated or re-crossed with the parental forms. The significant genetic diversity that was involved in hybridization provided intensive generation of varying forms. At the same time, special attention was paid to the detailed study of plants during the initial stages of breeding, since only recombination variability in the F_{2-4} generations ensures the production of new transgressive forms with respect to economically valuable traits [27].

1. Yield structure in spelt wheat samples (F_{5-11}) derived from hybridization of *Triticum aestivum* L. × *Triticum spelta* L. (*M*±SEM, Ukraine, Cherkasy region, 2012-2018)

Genotype	Maternal parent	Grain weigh per main ear, g	Ear length, cm	Grains per ear	Ear density, grains per 10 cm	Plant height, cm
		Semi-dwarf (60-84 cm)				
Average value per group		2.04±0.051	15.1±0.20	44±0.3	15.2±0.14	78±0.7
1786	Favoritka	2.02±0.063	15.5±0.22	44±0.4	15.5±0.17	82±0,8
1817	Khrust	2.56±0.090	18.0±0.28	46±0.4	14.5±0.13	75±0,7
$LSD_{0.95}$		0.07	0.6	2	0.6	3
Cv, %		9.28	10.8	3	3.9	5
Sx, %		3.41	3.9	4.5	3.9	3.8
		Undersized (85-104 cm)				
Average value per group		1.52±0.081	14.2±0.15	45±0.3	14.6±0.15	96±0.9
13	Panna	1.41±0.062	13.6±0.18	42±0.3	15.2±0.13	100±0,9
124	Ermak	1.88±0.089	12.9±0.15	45±0.3	14.3±0.10	92±0,8
179	Podolianka	1.47±0.050	13.1±0.16	46±0.3	15.6±0.15	103±0,9
1559	Kryzhinka	2.40±0.122	18.0±0.24	48±0.4	15.8±0.16	87±0,8
1674	Farandol	2.02±0.113	14.4±0.20	45±0.3	15.0±0.14	89±0,8
1694	Farandol	1.74±0.102	18.3±0.23	44±0.3	14.1±0.15	98±0,8
1755	Panna	2.33±0.131	17.1±0.22	46±0.4	14.7±0.15	98±0,9
$LSD_{0.95}$		0.06	0.5	2	0.6	4
Cv, %		13.45	14.3	3	18.9	7
Sx, %		3.94	3.5	4.4	3.8	4.2
		Medium-sized (105-119 cm)				
Average value per group		1.54±0.062	14.8±0.20	44±0.3	14.4±0.17	110±0.9
40	Panna	1.24±0.028	14.5±0.21	39±0.3	14.4±0.16	113±0,9
76	Kryzhinka	1.81±0.080	15.2±0.24	42±0.3	14.7±0.18	110±0,9
155	Panna	1.85±0.071	16.5±0.28	45±0.3	13.9±0.10	109±0,9
1721	Panna	1.58±0.049	17.4±0.31	42±0.3	13.9±0.11	106±0,9
1725	Kopilovchanka	1.53±0.052	17.3±0.29	45±0.4	13.7±0.09	110±0,9
$LSD_{0.95}$		0.06	0.5	2	0.6	4
Cv, %		6.34	12.6	2	4.7	3
Sx, %		3.8	3.6	4.5	3.7	3.6
		Tall (> 120 cm)				
Average value per group		1.75±0.060	14.1±0.20	44±0.3	13.2±0.10	125±1.1
86	Panna	1.89±0.091	13.2±0.16	45±0.3	14.7±0.15	122±1,1
1691	Krasnodarskaya 99	2.05±0.132	15.8±0.23	43±0.3	14.1±0.13	120±1,1
1695	Panna	2.70±0.149	16.1±0.25	45±0.4	15.3±0.18	129±1,5
1730	Favoritka	1.76±0.064	15.7±0.22	41±0.3	13.7±0.09	127±1,2
$LSD_{0.95}$		0.06	0.5	2	0.5	5
Cv, %		12.25	9.5	2	11.6	2
Sx, %		3.4	3.5	4.5	3.9	4.0

Note. *Cv* — coefficient of variation, Sx — relative standard error. The paternal form of all genotypes was spelt wheat from the foothills of the Carpathians. Genotype numbers are listed according to the field trial records.

Spelt wheat samples characterized by a significant diversity in morphobiological features were isolated among the offspring by individual and family selection. The obtained collection includes early maturing forms small in height, with high winter and frost resistance and other valuable traits. Some forms exceeded the original varieties in terms of yield, grain protein and fibrin content, and grain weight per ear (Table 1).

Spelt wheat is distinguished by its tallness [28, 29]; therefore, it is important to reduce the stem height while maintaining a high content of protein and fibrin. Our collection includes forms that differ significantly in plant height. The range of variability for this trait was 52-129 cm.

According to some reports [15, 30, 31], the hybrids obtained by crossing different wheat types, occupy an intermediate position between the parents in terms of plant height. However, the scientific literature describes the facts of dominance and overdominance of a tall parent [14, 32, 33]. Selective (due to additive gene interaction) and hybrid (due to complementary interaction of genes) dwarfism are also recorded in the offspring [34].

A comparative study of more than 200 accessions of spelt wheat and the original forms indicates a different pattern of plant height inheritance, from typical intermediate to heterosis and dominant dwarfism. The created samples were divided into tall (over 120 cm in height), medium-sized (105-119 cm in height), undersized (85-104 cm in height), semi-dwarf (60-84 cm in height) and dwarf (less than 60 cm in height) according to the classification of Dorofeev et al. [25]. The most numerous and productive were the undersized and medium-sized groups.

Published research information contains few reports on the genetic control of plant height in *T. spelta*. In generations F_5 from crosses of tall forms, tall offspring were obtained, which suggests that tall stems are characteristic of spelt plants [1]. Upon spelt hybridization with common wheat varieties carrying dominant or recessive dwarf genes, there are various types of gene interactions (complementary, epistatic, polymeric) and the formation of offspring with a wide range of variability in plant height.

Spelt wheat has a long, loose ear, which leads to low grain number per ear. In breeding, it is important to increase ear density, which, in turn, will improve productivity.

The speltoid shape of the ear of hexaploid wheat species is controlled by *S* gene, the dominant allele of which affects ear length and density. In addition, *C* gene influences spike length, that is, the dominant allele causes its shortening [34]. When spelt wheat with dominant alleles of *S* gene is crossed with soft wheat having *C* gene, the ear length and density are mainly inherited in generations according to an intermediate type. Thus, the samples obtained by us occupied the intermediate position between the initial forms in the spike length, and were closer to the spelt wheat in terms of the spike density (less than 16 spikelets per 10 cm of the spike length).

The undersized and tall specimens showed a moderate variation in grain weight per the main spike (Cv = 12.25-13.45%). All studied samples showed a significant increase in this parameter, with the exception of Nos. 13 and 40. The sample No. 1559 significantly exceeded the group standard with regard to the grain number per spike (48 grains). For other forms, except for Nos. 13 and 40, the values were comparable to the standard.

In hybridization of soft wheat with spelt wheat, it is important to maintain grain protein and fibrin content at a high level. When a parental form of soft wheat rich in grain protein and fibrin is crossed with spelt wheat samples poor in these substances, the offspring inherit the traits of the worst parent [16, 19]. To create spelt wheat varieties, the hard wheat varieties also valuable in other grain quality parameters should be involved in hybridization. In our studies, such a variety was winter wheat variety Panna. The offspring from crosses of this variety with spelt wheat had the highest grain protein and fibrin levels, in particular, for No. 40 (medium-sized) and No. 13 (undersized), the grain protein content reached 30.1 and 27.2%, respectively, with the fibrin content of 63.2 and 56.5%, respectively, which significantly exceeded the average value per group (Table 2).

2. Grain quality and yields of the best spelt wheat samples (F_{5-11}) derived from hybridization of *Triticum aestivum* L. × *T. spelta* L. (*M*±SEM, Ukraine, Cherkasy region, 2012-2018)

Genotype	Maternal parent	1000-grain weight, g	Bushel weight, g/l	Vitreousness, %	Protein content, %	Gluten		Yield, t/ha	±to averaged value per group	Grain threshing, %
						%	quality group			
Semi-dwarf (60-84 cm)										
Average value per group		49.8±0.20	655±15.1	74±0.6	18.2±0.14	38.5±0.28	–	5.75±0.231	–	78
1786	Favoritka	51.5±0.35	650±16.2	82±0.9	20.4±0.09	41.6±0.21	III	5.78±0.250	+0.03	75
1817	Khrust	50.0±0.38	675±15.0	87±1.0	22.0±0.12	44.7±0.24	II	6.47±0.281	+0.72	70
$LSD_{0.95-0.99}$		2.2	28	3	0.1	0.3	–	0.22	–	3
Cv, %		2.0	2	2.78	2.67	2.54	–	4.05	–	9
S_X, %		4.0	3.6	4.1	0.5	0.8	–	3.81	–	3.4
Undersized (85-104 cm)										
Average value per group		50.2±0.25	660±15.2	75±0.6	16.8±0.18	34.2±0.38	–	5.12±0.201	–	77
13	Panna	50.6±0.21	650±14.9	89±0.4	27.2±0.07	56.5±0.16	II	4.42±0.184	–0.70	80
124	Ermak	53.8±0.18	660±13.3	74±0.5	17.9±0.19	37.4±0.37	I	5.05±0.242	–0.07	84
179	Podolianka	47.5±0.28	640±15.2	85±0.4	22.7±0.13	47.8±0.25	II	4.56±0.221	–0.56	78
1559	Kryzhinka	64.4±0.14	660±12.1	82±0.5	21.0±0.14	43.7±0.29	I	6.27±0.290	+1.15	72
1674	Farandol	55.2±0.18	680±14.8	66±0.5	16.2±0.22	34.7±0.40	III	5.74±0.248	+0.62	75
1694	Farandol	50.7±0.20	660±12.2	74±0.5	18.3±0.14	38.5±0.28	II	5.12±0.209	0.0	77
1755	Panna	50.7±0.19	660±12.4	75±0.5	18.3±0.15	38.5±0.32	II	5.87±0.261	+0.75	78
$LSD_{0.95-0.99}$		2.1	29	3	0.1	0.3	–	0.20	–	3
Cv, %		13.1	5	9	11.4	14.2	–	11.8	–	10
S_X, %		3.8	3.9	3.8	0.6	0.9	–	3.9	–	3.5

Continued Table 2

Medium-sized (105-119 cm)										
Average value per group		49.3±0.25	650±15.2	78±0.5	18.8±0.16	37.2±0.34	–	–	–	76
40	Panna	49.1±0.24	650±16.0	92±0.3	30.1±0.05	63.2±0.11	II	4.26±0.183	–0.61	78
76	Kryzhinka	50.3±0.20	650±15.1	85±0.4	25.2±0.07	52.1±0.15	II	5.15±0.208	+0.28	80
155	Panna	52.0±0.15	675±12.9	81±0.5	20.2±0.12	41.5±0.22	II	5.36±0.251	+0.49	92
1721	Panna	44.5±0.29	650±17.2	84±0.4	21.6±0.10	47.6±0.19	II	4.79±0.222	–0.08	77
1725	Kopilovchanka	48.7±0.27	670±12.1	75±0.5	16.2±0.21	36.7±0.38	I	5.70±0.271	+0.83	90
$LSD_{0.95\text{-}0.99}$		2.0	28	3	0.1	0.3	–	0.18	–	3
Cv, %		4.7	3	11	14.8	15.9	–	9.85	–	12
Sx, %		3.8	3.7	4.1	0.5	0.8	–	3.7	–	3.8
Tall (> 120 cm)										
Average value per group		48.2±0.26	660±15.7	75±0.5	18.7±0.15	38.7±0.32	–	5.87±0.257	–	75
86	Panna	45.2±0.25	660±15.1	87±0.4	26.2±0.08	54.0±0.15	I	5.21±0.228	–0.66	78
1691	Krasnodarskaya 99	55.1±0.17	665±14.0	82±0.5	22.3±0.06	47.8±0.13	II	5.77±0.262	–0.10	80
1695	Panna	50.3±0.19	670±12.1	74±0.5	19.0±0.13	40.5±0.25	I	6.45±0.311	+0.58	80
1730	Favoritka	45.8±0.23	680±11.2	62±0.6	15.2±0.23	37.2±0.38	I	4.86±0.190	–1.01	78
$LSD_{0.95\text{-}0.99}$		1.9	30	3	0.1	0.3	–	0.23	–	3
Cv, %		7.7	3	12	10.6	11.7	–	7.17	–	6
S_X, %		3.5	4.1	3.7	0.5	0.8	–	3.9	–	3.8

Note. *Cv* — coefficient of variation, Sx — relative standard error. The paternal form of all genotypes was spelt wheat from the foothills of the Carpathians. Genotype numbers are listed according to the field trial records. The significance level of $P_{0.99}$ was used when processing data on protein and gluten content. Dashes indicate that statistics and the group mean were not determined.

For bread-making quality of grain, qualitative rather than qualitative gluten parameters are decisive. Physical parameters such as color, stretch, elasticity and deformation index (GDI) greatly influence the dough formation and bread yield. According to GSTU 3768:2010 [35)], gluten of quality group I should be light gray or gray in color, elastic, with extensibility within 10-20 cm and gluten deformation index (GDI) of 45-85 units of Gluten deformation meter VDK-M (Ukraine). The quality group can be revised if the deformation index goes beyond the limits acceptable for group I, since it is the GDI that is the most important indicator of the gluten quality. In our study, six samples have gluten of quality group I (see Table 2). Especially noteworthy is the No. 86 of the tall group, which also stood out for its high gluten content (54.0%).

Vitreousness is an important trait that determines the suitability of grain for various end products and influences the processing and milling. The grain vitreousness of the spelt wheat samples studied by us ranged from 62 to 92%. The highest it was in Nos. 40 (92%), 13 (89%) and 1817 (87%). The wheat grain is considered vitreous for the values exceeding 70%, half-vitreous for 50-69%, semi-mealy for 21-49%, and mealy for < 20%. The grain of all samples in the experiment was vitreous, with the exception of Nos. 1674 and 1730, which had a semi-vitreous endosperm consistency.

The 1000-grain weight in the studied samples ranged from 44.5-64.4 g. A significant increase in this indicator as compared to the average group standard was recorded in samples Nos. 124 (53.8 g), 1559 (64.4 g), 1674 (55.2 g), 155 (52.0 g) and 1691 (55.1 g). The grain yield of Nos. 76, 155, 1559, 1674, 1695, 1725, 1755 and 1817 significantly exceeded the standard. Worth noting is the No. 1695 of the tall group, which combines a productivity of 6.52 t/ha with high grain quality (1000-grain weight of 50.3 g, grain protein content of 19.0%, 40.5% of gluten of the quality group I) and the No. 155 of the medium-sized group, in which all quality and productivity indicators significantly exceeded the group's standards.

Spelt wheat grain is difficult to thresh because of the spikelet fragility and the presence of coarse spikelet hulls. Unlike soft wheat, spelt wheat harbors the recessive allele *q* of the *Q* gene, which controls the character of grain threshing (easy or difficult). The homozygotes for the *q* allele have spikes of a speltoid type (long, fragile and loose) which are poorly threshed [36]. In addition, the threshing is influenced by the type of spikelet, which in hexaploid wheat species is controlled by the *Tg* gene recessive allele *tg* in a homozygous state [36]. Since spelt wheat has dominant alleles of this gene, its spikes possess coarse spikelet hulls, which negatively affects threshing. In the offspring from crossing soft wheat with spelt wheat, various combinations of alleles of *Q* and *Tg* genes appeared. In this regard, both different threshing capacity and unequal structure of the spikelet hulls were recorded. Probably Nos. 76, 155, 1695, and 1725 have the *QQtgtg* genotype, which improves grain threshing (80-90%).

The growing season of spelt wheat lasts 7-10 days longer compared to soft wheat. Among the samples studied by us, forms were distinguished, the periods of heading and ripening of which were comparable to those of early maturing varieties of common wheat. Nos. 1674 and 155 had a 280-285-day growing season, while their yield (5.74-5.86 t/ha) significantly exceeded the standard.

In 2013 and 2015, spelt wheat crops were affected by brown rust (*Puccinia recondita* Rob. ex Desm f. sp. *tritici*). Nos. 13 and 124 showed high resistance to the pathogen. The lesion intensity was less than 5% of the leaf surface, which corresponds to 8-9 points on the resistance scale. It is obvious that these samples inherited the resistance trait from the parental forms (the common wheat varieties Ermak and Panna, as well as the original form of spelt wheat),

which exhibit high resistance to brown rust. The genes for resistance to this disease in common wheat are in a heterozygous state, and therefore not all plants of the offspring of the same parents were resistant to the disease.

The tests of the breeding samples obtained by us are still ongoing. Among them, the search for new donors of valuable traits is being successfully carried out. As a result, the winter spelt wheat variety Europe was created, which is listed in the State register of plants suitable for growing in Ukraine (since 2015). Nos. 124 and 155 after reproduction will be subjected to the State Scientific and Technical Expertise.

Variety Europe (breeding sample No. 1725) is an awned form of spelt wheat, in which 90% of the grain is separated from the hulls during threshing. The variety derived from hybridization of Kopilovchanka winter bread wheat and spelt wheat upon multiple individual selection. This is a winter type variety with a plant height of 110 cm, a grain protein content of 17%, a gluten content (the quality group I) of 38%, a 1000-grain weight of 47 g, and a bushel weight of 670 g/l. During the period of the State Scientific and Technical Expertise (2012-2015), the variety had an average yield in the forest-steppe zone of 5.82 t/ha. The variety is resistant to brown rust, powdery mildew, snow mold and tolerant to yellow spot, fusarium head blight and root rot. Breeding sample No. 124 was created by hybridization of soft winter wheat variety Ermak with spelt wheat. This is a winter type undersized sample with a plant height of 92 cm. The growing season lasts 290-295 days (a mid-season type). The spikes are awnless, long, loose. The sample shows high grain quality, in particular, the 1000-grain weight of 53.8 g, the protein content of 17.9%, the gluten content (the quality group I) of 37.4%, the productivity is 5.05 t/ha. Selection sample Nos. 155 was obtained by hybridization of winter soft wheat variety Panna with spelt wheat. The sample is of a winter type, medium-sized (109 cm in height), mid-season (290-295-day growing season), has an awnless, long (16.5 cm), loose spike, combines high grain quality (1000-grain weight of 52.0 g, bushel weight of 675 g/l, protein content of 20.2%, gluten content of 41.5%) with a productivity of 5.36 t/ha and threshing capacity of 92%.

Thus, more than 200 spelt wheat samples derived from distant hybridization of soft winter wheat and spelt wheat has been created. This collection includes unique recombinant forms that differ in economically valuable, morphobiological and biochemical traits. Spelt wheat sample No. 124 possesses a combination of valuable traits, in particular, the plants are of 92 cm in height and produce high quality grain (1000-grain weight of 53.8 g, protein content of 17.9%, quality group I gluten content of 37.4%). Spelt wheat sample No. 155 stands out for its high productivity (5.36 t/ha) and improved grain threshing capacity (92%). The variety Europe of winter spelt wheat created within the framework of this breeding program has been included in the State register of plants suitable for growing in Ukraine.

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