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BREEDING VALUE OF SPELTA IN THE EASTERN PART OF THE FOREST STEPPE OF UKRAINE

A.K. NINIEVA
Plant Production Institute nd. a. V. Ya. Yur'yev of NAAS, NCPGRU

The specimens of spelta genetical diversity are characterized by economical and biological traits in the eastern Forest-Steppe of Ukraine were characterized. The specimens-standards are selected. By means of hybridization of spelta specimens with soft wheat varieties, winter and spring lines of wheat type combining the productivity of bread wheat with spelta grain qualitative traits and showing selection value are created.

***Key words**: spelta, bread wheat, gene pool, hybrids, agronomical traits.*

Spelta (*Triticum spelta* L.) – is a cereal crop wich had been growing widely for a long time. Later it disappeared from plantings remaining only in small regions of Europe (Alpian and Pyrenian regions, Italy, is. Gotland in Sweden) and Middle Asia where the population preserve the elements of traditional culture. Up to the middle of the 20^{th} century spelta had been growing in the Carpathians [1, 2].

This crop is characterized by its resistance to a number of negative bio and abiotic factors including severe conditions of mountainous areas allowing not to use chemical means of protection or at least to reduce their use. Spelta has definite advantages over bread wheat by its nutritive value [1,3]. An interest to this crop is growing now from the point of view of organic farming and "healthy food".

A difficult threshing of grains because of dense coverage with sturdy scales is of a great problem for spelta growing and usage. This demands special equipment and extra energy expenditure to produce clean grains. Presence of pellicle doesn't allow to do qualitative planting with cereal seeders as unthreshed spikelets clog seed channels, and attempts to rethresh them leads to kernels' damage that results in their spouting reduction. Another negative point is spikelet breakage when it was not harvested after ripening. Spelta can't compete with the main wheat species genetically related to it – bread wheat. It concerns also spelta's modern varieties created in breeding institutions by means of hybridization with varieties of bread wheat. Although in unfavorable seasons spelta can surpass bread wheat yield [4].

So the way to revival of the crop in order to provide the consumers with its produce lies through its improvement. On the other hand spelta was used as the initial material for breeding of bread wheat. Owing to genetical closeness of these 2 species – presence in both of them ABD genome – they are genetically compatible and can easily exchange genetical materials [1]. Under the conditions of the eastern part of the Forest-Steppe of Ukraine, up to the present, spelta has not been studied systematically from the both points of use: as for bread wheat breeding and for spelt varieties creation.

The purpose of the research was to evaluate spelta diversity by the complex of agronomic and biological traits and prospects of its usage in breeding.

The materials of the research were 15 samples of spelta from the National Plant Genebank of Ukraine which belong to European and Asian subspecies. [5]. 11 samples have winter type of development: UA0300076 *var. arduini,* Great Britain (GBR); UA0300301 Rubiota, (CZE); 3 cultivars from Austria (AUT): Bauländer UA0300101, *var. duhamelianum*; Schwabenkorn UA0300102, *var.amissum*; Frankenkorn UA0300103, *var. duhamelianum*; 5 samples from Serbia (SER): NSS 1/02 UA0300259, *var. duhamelianum*; NSS 1/01 UA0300246, *var. album*; NSS 3/01 UA0300227, *var. neglecta*; NSS 6/01 UA0300300, *var. duhamelianum*; cultivar Nirvana UA0300302; UA0300306 *var. duhamelianum*, Sweden (SWE); UA0300075 *var. griseoturanorecens*, Tajikistan (TJK). 4 samples are of a spring type of development: UA0300218 *var. caeruleum,* Tridentina, Italy (ITA) and UA0300074 *var. caeruleum,* Spain (ESP) by their ecotype belong to Iberian spelta; UA0300304 *var. album*, Australia (AUS); UA0300111 *var. album,* Canada (CAN) – to Bavarian spelta. Spelta samples were kindly presented by All-Union Institute of Plant Growing named after M.I. Vavilov (Russia, Saint Peterburg), the Gene Bank of Czech Republic and Institute of Field Cropping and Vegetable Growing "Novyy Sad" (Serbia). In interbreeding with the spelta samples there were used varieties of bread wheat of Ukrainian breeding institutions: winter wheat – Vasylyna, Octava, Bilosnizhka and Astet; spring ones – Heroinya, Kharkivska 26, Kharkivska 28 and also Sunnan (SWE).

Methods of investigation. The investigations were carried out in 2007-2012 in the fields of 8-field crop rotation of Plant Production Institute nd. a. V.Ya. Yur'yev of NAAS that is located 20 km away to the East of the city of Kharkiv.

The samples of spelta and bread wheat were sown with hand seeders on 1 m^2 plots with spacing between rows 15 cm, planting rate 500 seeds per 1 m^2, in 3 replications. The analysis of yield structure was carried out according to metods of All-Union Institute of Plant Growing [6]. After the full maturity, sheaves were picked out: 25 plants of parental forms and all the plants of the hybrids. Ecological plasticity of the samples was estimated by the methods of Eberhard and Russel interpreted in the methodical recommendations of B.P. Gur'yev. [7]. Variation of the separate traits over the years was evaluated according to the coefficient of variation V% [8]. The gluten and protein content was measured by the method [9]. To assess the significance of differences between the variants of experiments, the average errors were calculated and criteria of Student were determined.

The hybridization of spelta samples with bread wheat was conducted by generally adopted procedure with "twell-method" pollination.

Beginning from F_2, the plants were selected that surpass the best parental forms by spike's traits, afterwards from them were laid families from which a stabilizing selection was carried out.

Weather conditions during the years of studies differed as to main meteorological indices. In 2008 year optimal ratio of daily-mean temperatures and rainfalls was observed during critical periods of plants development. It promoted the manifestation of differentiation of the samples by resistance to lodging and diseases, formation of high yield.

In 2009, April was cool and dry, which adversely affected on plant density.

During the vegetation, daily-mean temperatures were close to perennial values and the amount of rainfalls was lower. It created severe conditions for growth and development of plants of spring spelta and bread wheat.

In 2010, daily-mean temperatures exceeded perennial ones during the whole period of vegetation. The critical stages of shooting, heading and flowering were under dry conditions that resulted in a low level of grain yield. A favorable hydrothermal conditions were observed at grain filling stage.

During the vegetation period of 2011, at the initial growth stages of the plants of spelta and spring bread wheat, the hydrothermal regime was favorable. However, high indices of maximal temperatures in the 2-nd and 3-rd decades of July and 1st decade of August affected negatively on passing the final stages of plant growth that affected negatively on grain yield formation.

Results of the investigation. The first step in studying spelta collection was to define the standards for winter and spring samples, as the comparison with bread wheat is not correct. The main requirement to a standard sample was increased and stable level of manifestation of main indices of production in different years of investigations.

The cultivar Frankenkorn from the winter spelta collection corresponded with the requirements to the standard variety. It combines a high level of grain yield (5,89 t/ha) with shorter period of sprouting – earing (246 days) in the comparison with the other spelta samples, rather high lodging resistance (7,5 points), brown rust (7,5 points), winter resistance (7 points), it has a lower level of grain hulliness – 31% [10].

UA0300304 (AUS) is defined as a standard variety among the samples of spring spelta. Its grain yield is 3,53 t/ha, it is combined with resistance to brown rust – 8 points and increased productivity of tillering 1,3 [11].

As to the grain yield, among winter samples, NSS 3/01 and UA0300257 (SWE) samples are selected; among spring – UA0300111 (CAN) (table 1). They showed an increased genotypical effect and low variation that corresponds to trait's stability; the lowest sum of ranges = 3.

1. Ecological plasticity of spelta samples by crop capacity

№ of National Catalogue, sample name, origin country	Crop capacity, t/ha	Genotypic effect		Level of plasticity		Rank sum
		EI	rank	RI	rank	
Winter spelta*						
UA0300103, Frankenkorn, AUT (standart)	4,96	1,22	1	1,33	3	4
UA0300227, NSS 3/01, SER	3,64	-0,10	2	0,71	1	3
UA0300300, NSS 6/01, SER	5,03	1,29	1	2,13	3	4
UA0300302, Nirvana, SER	4,24	0,50	2	1,61	3	5
UA0300257, SWE	3,82	0,08	2	0,39	1	3

Spring spelta**						
UA0300304, AUS (стандарт)	3,53	1,11	1	2,90	3	4
UA0300074, ESP	1,71	-0,71	2	0,27	2	4
UA0300218, Tridentina, ITA	2,49	0,07	2	-1,94	2	4
UA0300111, CAN	3,47	1,05	1	2,09	2	3

Note: * – data for 2008-2009, 2011; ** – data for 2008-2011.

The samples of spring spelta were characterized by moderate variability (V=6-10%) as to the number of spikelets in the spike, by hulliness and 1000 grain weight (5,1%, 7,9% and 9.6%, respectively). In winter spelta, the variation level was a bit higher than in spring spelta. The variation range was significant (V=11-20%) as to the number of spikelets per spike and 1000 grain weight (11,6% and 16,6%) (table 2).

2. Variation of valuable agronomic traits of spelta, V%

Traits	Winter spelta*		Spring spelta**	
	avarage	min-max	avarage	min-max
Crop capacity	60,3	32,2-91,4	32,7	20,7-50,1
Productive tillering	58,6	34,3-93,1	43,3	33,7-51,8
Height	25,3	14,3-48,5	14,9	11,9-19,4
Length of spike	18,4	11,9-23,2	13,4	8,8-18,9
Number of spikelets per spike	11,6	6,1-27,5	5,1	4,5-5,8
Grain number per spike	33,8	14,6-66,5	23,1	10,4-30,6
Grain weight per spike	48,7	30,6-86,8	28,6	21,8-33,7
1000 grains weight	16,6	6,2-30,9	9,6	3,9-18,1
Hulliness	20,3	4,0-47,6	7,9	5,3-9,1

Note: * – data for 2008-2009, 2011; ** – data for 2008-2011.

Among spelta collection samples the carriers of high level of manifestation of valuable agronomic traits were selected:

– of crop capacity and its elements: of winter spelta UA0300300 NSS 6/01 selected by crop capacity traits (5,03 t/ha) and grain weight per spike (2,04 g); UA0300259 NSS 1/02 (SER) selected by high weight of 1000 grains (47,79 g), UA0300257 (SWE) – by number of grains per spike (61,6 pcs) and UA0300075 (TJK) – by productive tillering (2,9); spring spelta – UA0300218, Tridentina (ITA), which was selected by grain number per spike (39 pcs), grain weight per spike (1,5 g), 1000 grains weight (37,15 g);

– high lodging resistance: of winter spelta – Nirvana (SER) (7 points), spring

spelta UA0300074 (ESP) (9 points);

– resistance to brown rust: of winter spelta – NSS 1/02 and Nirvana (SER) (8 points each).

Grain quality indices of spelta were studied on grain grown in 2008 and 2009. Protein content of winter spelta samples during 2008 and 2009 varied from 15,2% to 17,5% on average 16,4%. In spring spelta those indices amounted from 16,5% to 18,0% and 17,3%, respectively. Gluten content of winter spelta was from 33,6% to 43,9%, on average – 38,5%, and of spring samples – from 31,9% to 40,4%, on average 37,7%. In comparison with winter bread wheat of cultivar Vasylyna the corresponding indices were such as: protein content from 12,7% to 14,1%, gluten content – from 29,4% to 32,5%; in spring bread wheat Kharkivska 29 protein content ranged from 13,5% to 15,2%, gluten content from 30,3% to 33,5%.

It is important to note that samples with rather large-sized grains of both winter and spring spelta had a high protein content of grains. The winter sample NSS 3/01 (SER) had 1000 grains weight 45,4 g and protein and gluten contents – 17,5% and 43,9%, respectively. In the winter spelta variety Nirvana (SER), 1000 graims weight was 47,8 g and protein content – 17,4%, gluten – 41,6%. Among spring spelta samples, the Spainian spelta (UA0300074) was allocated for its high protein content – 18,0% and gluten – 39,5%, the gluten belonged stably to the 2^{nd} group by quality.

Together with the positive properties of spelta, as it was above mentioned, it has some disadvantages – difficult threshing and spike breakage that makes it not very technological and impedes it usage in the industry. On the average, winter spelta hulliness is 33%, at the same time bread wheat hulliness is 24%. Besides, an important disadvantage of existing varieties and forms of winter spelta is insufficient winter resistance under the conditions of the eastern Forest-Steppe of Ukraine [12].

In order to overcome these disadvantages, a number of crosses of spelta samples with modern bread wheat varieties was carried out. Under the extremal conditions of overwintering in 2009-2010 at low temperatures up to -30 °C and ice crust, the hardy was F_2 of reciprocal hybrids NSS 1/02 x Octava; UA0300075 x Vasylyna; UA0300075 x Octava and unidirectional hybrids NSS 6/01 x Vasylyna and Bilosnizhka x UA0300075, as well. In the progeny of backcrosses, the most hardy were: (UA0300075 x Vasylyna) x Vasylyna; (Bilosnizhka x NSS 1/01) x NSS 1/01 and **(**Bilosnizhka x NSS 1/01) x Bilosnizhka. In F_1 hybrids, winter resistance was shown in: UA0300075 x Vasylyna; UA0300075 x Octava; Bilosnizhka x NSS 1/01; Rubiota x Astet; Astet x Rubiota. It should be noted that spelta from Tajikistan UA0300075 has a very low winter resistance, so resistance to overwintering of F_1, F_2 and BC_1 hybrids is generally caused by bread wheat and this way is perspective for spelta breeding improvement according to this trait.

At present, 85 spring lines have been developed which by their phenotype correspond to bread wheat, easily threshed, have increased protein and gluten content and high level of productivity. Particularly, as to the data of spike productivity, such samples were picked out: NAK 170/11, NAK 200-1//11, NAK 181-п/11, NAK 185/11, NAK 251/11, NAK 195-1/11, NAK 187-2/11. The samples NAK 170/11, NAK 200-1/11, NAK 181-п/11 were stand out according to the trait – grain weight per spike which amounted 1,82 g, 1,78 g and 1,60 g, respectively, at the same time as

spring bread wheat cultivars Kharkivska 26 and Kharkivska 28 had 1,51 g and 1,58 g, respectively. As for the grain number per spike, several lines were selected with the level of this trait near to the level of bread wheat varieties. These are NAK 170/11 (41,5 pcs), NAK 185/11 (40,4 pcs) and NAK 251/11 (41,8 pcs).

24 lines were selected by 1000 grain weight. They exceeded the indices of spring bread wheat varieties Kharkivska 26 (34,8 g) and Kharkivska 28 (38,3 g) by 20%. The lines NAK 195-1/11, NAK 187-2/11 and NAK 200-1/11 showed the highest exceeding, their 1000 grain weight is 48,1 g, 46,1 g та 45,5 g respectively.

The gluten content in the seed of bread wheat varieties Kharkivska 26 and Kharkivska 28 was 30,8% and 27,2%, respectively (quality group – I) and protein content – 15,7% and 17,2%. Among the lines of spring bread wheat type created with the participation of spelta, were selected by the quality indices:

- gluten of the 1st quality group was inherent in the lines NAK 180-п/11 and NAK 254-2/11, but its content doesn't considerably exceed bread wheat indices, it was 28,8% and 29,2%, respectively;
- the highest gluten content was observed in the lines of NAK 221-1/11, NAK 221-п/11 and NAK 228-п/11: 38,4%, 37,6% та 37,6%, respectively. The quality group of which was 2nd;
- the lines NAK 196-п/11, NAK 222-п/11, NAK 224-п/11, NAK 228-п/11, NAK 197-п/11, NAK 202-п/11, NAK 221-1/11 and NAK 181-п/11 surpassed bread wheat by protein content up to 16%.

Conclusion. The samples-standards were defined: for winter spelt UA0300103 Frankenkorn (AUT) and for spring spelt UA0300304 (AUS).

The spelt samples with the combination of genotypic effect and ecological plasticity by yield feature were defined: among winter samples NSS 3/01 (SER) and UA0300257 (SWE); among spring samples – UA0300111 (CAN).

By a high level of manifestation of agronomic traits, the following samples are characterized: winter spelt samples NSS 6/01, NSS 1/02 (SER), UA0300257 (SWE), UA0300075 (TJK); spring spelt ones UA0300304 (AUS) and Tridentina (ITA) – as for yield indices and its elements; winter spelta samples Nirvana (SER), spring spelta UA0300074 (ESP) – resistance to lodging; winter spelta NSS 6/01 and Nirvana (SER) – resistance to brown rust.

Spelta samples are distinguished by high protein content – on average 16,4% in winter spelta, 17,3% in spring spelta; gluten content – 38,5% in winter, 37,7% in spring samples.

By hybridization of the spelta samples with modern bread wheat varieties, winter hardy hybrid populations of winter spelta and high productive lines of spring bread wheat are developed. They are the initial materials for breeding of the both crops under the conditions of the eastern part of Forest-Steppe of Ukraine.

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А. К. Ниниева

Селекционная ценность спельты в условиях восточной части Лесостепи Украины

В условиях восточной части Лесостепи Украины спельта систематически не изучалась с точки зрения, использования её в качестве исходного материала как для селекции пшеницы мягкой, так и для создания сортов спельты как таковой. Поэтому целью данного исследования было оценить разнообразие спельты, сосредоточенное в Национальном генбанке растений Украины, по комплексу хозяйственных и биологических признаков и определить перспективность его использования в селекционном процессе.

В результате изучения выделены образцы-стандарты для озимой и яровой спельт, характеризующиеся повышеным и стабильным уровнем проявления основных показателей продуктивности в разные годы. Для спельты озимой в качестве стандарта определен сорт Frankenkorn (AUT); для спельты яровой – образец UA0300304 (AUS). Выделены образцы спельты, сочетающие высокий генотипический эффект и экологическую пластичность по урожайности: среди озимых образцов NSS 3/01 (SER) и UA0300257 (SWE); среди яровых – UA0300111 (CAN). Высоким уровнем проявления ценных хозяйственных признаков характеризуются образцы спельты озимой – NSS 6/01, NSS 1/02 (SER), UA0300257 (SWE), UA0300075 (TJK); спельты яровой – UA0300304 (AUS) и Tridentina (ITA) – по показателям урожайности и ее элементов; образцы спельты озимой – Nirvana (SER), спельты яровой UA0300074 (ESP) – по устойчивости к полеганию; образцы спельты озимой – NSS 6/01 и Nirvana (SER) – по устойчивости к бурой ржавчине.

Образцы спельты характеризуются высоким содержанием в зерне белка – в среднем 16,4% у озимой, 17,3% у яровой; клейковины – 38,5% у озимых, 37,7% у яровых образцов. Причем эти свойства сочетаются с крупностью зерна: озимый NSS 3/01 (SER) имел массу 1000 зерен 45,4 г, содержание белка 17,5%, клейковины 43,9%; у озимого сорта Nirvana (SER) – соответствующие показатели составили 47,8 г, 17,4%, 41,6%. Из яровых образцов по содержанию белка и клейковины выделился UA0300074 (ESP) – 18,0% и 39,5% соответственно. Клейковина относится ко второй группе качества.

С целью преодоления отрицательных свойств спельты – трудного вымолота зерна и ломкости колоса проведена гибридизации образцов спельты с современными сортами пшеницы мягкой. Созданы зимостойкие гибридные формы спельты озимой из комбинаций NSS 1/02 (SER) х Октава; UA0300075 (TJK) х Василина; UA0300075 (TJK) х Октава; NSS 6/01(SER) х Василина и др.; высокопродуктивные высокобелковые линии пшеницы мягкой яровой 187-2/11, NAK 170/11, NAK 200-1//11, NAK 181-п/11 и др. Их целесообразно использовать в качестве исходного материала для селекции обеих культур в условиях восточной части Лесостепи Украины.

***Ключевые слова**: спельта, пшеница мягкая, генофонд, гибриды, хозяйственные признаки.*

A. K. Ninieva

Breeding value of spelta under the conditions of eastern part of Ukrainian Forest-Steppe

Under the conditions of the eastern Forest-Steppe of Ukraine, the spelta did not studied systematically from the point of view of its use as a source material as for bread wheat breeding as for the creation of spelta varieties. Therefore, the aim of this study was to evaluate a spelta diversity accumulated in the National Plant Genebank of Ukraine, for a range of economic and biological characteristics and to determine

the prospects of its use in the breeding process.

As a result of the study, standard samples were identified for winter and spring spelt, that are characterized by increased and stable expression of the basic traits of productivity in different years. The cultivar Frankenkorn (AUT) is defined as a standard for winter spelta; the sample UA0300304 (AUS) — for spring spelt. The spelta samples combining high genotypic effect and environmental plasticity for productivity are identified: the winter samples NSS 3/01 (SER) *and UA0300257 (SWE); the spring one UA0300111 (CAN). High manifestation level of agronomic and economic valuable traits are characteristic for winter spelta NSS 6/01, NSS 1/02 (SER), UA0300257 (SWE), UA0300075 (TJK); spring spelta UA0300304 (AUS) and Tridentina (ITA) — in terms of yield and its elements; for winter spelta – Nirvana (SER) and spring UA0300074 (ESP) — on lodging resistance, for winter spelta NSS 6/01 and Nirvana (SER) — for resistance to leaf rust.*

Spelta samples are characterized by high protein content in grain — an average of 16.4% in winter spelta, 17.3% in the spring; gluten content is 38.5% in winter, 37.7% in spring samples. Moreover, these properties are combined with grain size: winter sample NSS 3/01 (SER) had 1000 grain weight 45.4 g, protein content of 17.5%, gluten content 43.9%, in the winter variety Nirvana (SER) the corresponding characteristics were 47.8 g, 17.4%, 41.6%. From the spring samples, the highest protein and gluten content indicate the UA0300074 (ESP) — 18,0% and 39,5% respectively. The gluten belongs to the second quality group.

In order to overcome the negative characteristics of spelt — hard grain threshing and brittle spike, hybridization of spelta samples with modern varieties of bread wheat was carried out. There were obtained winter-hardy hybrid forms from the combinations of winter spelta: NSS 1/02 (SER) x Octava; UA0300075 (TJK) x Vasilina; UA0300075 (TJK) x Octava; NSS 6/01 (SER) x Vasilina etc.; high productive and high protein lines of bread spring wheat 187 – 2/11, NAK 170/11, NAK 200 – 1 / / 11, NAK 181-p/11 etc. They could be used as a starting material for the breeding of the both crops in the eastern part of the Forest-Steppe zone of Ukraine.

Key words: *spelta, bread wheat, gen pool, hybrids, economic traits.*