

Analytical studies of new genetic sources of *Nordeum vulgare* L. *sensulato* on ecological adaptability in the conditions of the center of the European part of Russia

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Abstract. Studies to evaluate new genetic forms of spring barley were carried out in 2020-2022. in the conditions of the center of the European part of Russia (Ryazan region) on the following varieties: Znatny, Pamyati Chepeleva (Russia); Kufal, Reider (Belarus); KVS Harris, KVS Vermont, Bente, Ellinor (Germany); LG Nabucco, Rapid (France); Laureate (Switzerland), regionalized in the period 2018-2020. It was established that the varieties Znatny - 6.38 t/ha, Ellinor - 6.02 t/ha and Kufal - 5.98 t/ha had the highest average yield. According to the length of the spike (≥ 8.0 cm), the varieties Bente and Znatny stood out. It has been established that the varieties Pamyati Chepeleva and Laureate have the highest productive bushiness (≥ 4.0), the varieties Kufal, Reider, Bente have a high grain size (≥ 50.0 g). According to a number of statistical indicators for assessing adaptability, the following varieties were identified: in terms of the level of yield and plasticity of the variety - Znatny and Ellinor (more than 100.0%); according to the coefficient of adaptability - Znatny, Kufal, KVS Harris, KVS Vermont, Ellinor and Rapid ($K.A. > 1.0$); in terms of phenotypic stability (1.22...1.58) – Bente, KVS Harris, Noble, Ellinor and Rapid; according to the level of homeostasis (> 0.30) - Bente, Noble and Ellinor; by the minimum value of the range of yield (< 0.30) - Bente, KVS Harris, KVS Vermont, Noble; for the realization of the yield potential ($\geq 80.0\%$) - Znatny, Kufal, KVS Harris, Bente and Ellinor; in terms of stress resistance - Bente, KVS Harris, Ellinor and Noble; according to the genetic flexibility of the variety - Noble and Rapid. The principle of ranking the best varieties made it possible to single out the varieties Znatny, Bente and KVS Harris, which took the first, second and third places in the rating scale, respectively. Analysis of the correlation dependence of adaptability indicators on the yield of new varieties revealed a significant contribution of the level of variety stability, adaptability coefficient, homeostatic level, realization of the yield potential of varieties and genetic flexibility ($r = +0.502...+0.958$).

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1 Introduction

Nordeum vulgare l. *sensulato* (spring barley) is a key grain fodder and fodder crop, which forms an increased yield (compared to other grain fodder crops) due to precocity and drought resistance [1–2].

One of the topical subjects of modern discussion is the problem of observed and upcoming climate changes, both globally and in relation to agronomy [3–5]. Studies conducted in the last century have shown that in the conditions of the continental climate of the Russian Federation, the most important factor determining the average annual changes in the productivity of cultivated crops is meteorological conditions [6–7].

The high variability of weather conditions and their abnormal phenomena (drought, hail, waterlogging during the harvesting period, etc.) both in the world and in many regions of Russia leads to a downward trend in the growth rate of gross crop yields [8].

The use of a limited set of parental forms narrows the hereditary diversity of the created varieties and exacerbates the problem of their resistance to unfavorable abiotic environmental factors. It is necessary to achieve synergy of indicators of high productivity and variety stability, which are often negatively dependent [9].

The successful implementation of breeding programs to create innovative varieties is closely related to the use of new source material. The manifestation of the reaction of the genotype to environmental factors is always voluminous and multifaceted; therefore, it is necessary to take a comprehensive approach to assessing the biological essence of its adaptive properties [10–12].

In this regard, the identification of new genetic sources of spring barley adaptability and stability of traits for the creation of varieties is becoming an increasingly popular task, and the problem of adaptation to unpredictable environmental factors is relevant.

The novelty of the research lies in a comprehensive analysis using various methods to identify the adaptive capacity of new varieties of spring barley against the background of various limiting environmental factors in the conditions of the center of the European part of Russia.

2 Materials and methods

Analysis of studies of the new gene pool of spring barley (in the amount of 11 issues: Znatny, Pamiati Chepelev (Russia); Kufal, Raider (Belarus); KVS Harris, KVS Vermont, Bente, Ellinor (Germany); LG Nabuco, Rapid (France); Laureate (Switzerland)) was carried out in 2020-2022. on the fields of the Ryazan branch of the Federal State Budgetary Scientific Institution "Federal Scientific Agroengineering Center VIM" in the collection nursery of the laboratory of selection and primary seed production against a natural background. All studied genotypes in the experiment had a two-row spike (subsp. *distichum* L.) of the nutans variety and a mid-season growing season (81-87 days).

The laying of the nursery was carried out in the third decade of April - the first decade of May using a seeder SSKF-7M. The area of the plot is 3 m², without repetitions. The seeding rate of germinating grains per 1 m² is 500, the predecessor is pure fallow.

Under pre-sowing cultivation, mineral fertilizers were applied at the rate of (NPK)64 a.i. in the form of azofoska (N₁₆P₁₆K₁₆). In the tillering phase, the crops were sprayed with a tank mixture of herbicides (Ballerina, SE - 0.4 l/ha + Magnum, VDG - 7 g/ha) with the addition of insecticide Borei, SC - 0.1 l/ha.

To assess the prevailing hydrothermal conditions, we used data on the amount of precipitation and temperature obtained at the meteorological station of the ISA branch of the FGBNU FNAC VIM. The weather conditions during the research period were unstable

and this made it possible to fairly objectively analyze the studied varieties in terms of yield and its structural components.

Harvesting took place in warm and dry weather during all the years of research with the Sampo-130 combine in the phase of full ripeness.

The basis of all calculations was the sign of "yield". The degree of modification variability of the trait (coefficient of variation (C_v , %)), the manifestation of the trait "yield" (mean, maximum and minimum values (X_i , max and min, respectively)), the correlation of parameters with yield (correlation coefficient (r)), the standard error of the mean value of the indicator ($\overline{XX} \pm SE_{\overline{XX}}$), were carried out using the methods appropriate for these studies using the Microsoft Office Excel computer program [12]. Indicators of the realization of the yield potential of the variety (RPV, %), coefficient of adaptability (K.A.), stability factor (SF), homeostaticity (Hom), yield range (d, %), level of stress resistance ($Y_1 - Y_2 = Y_{\min} - Y_{\max}$), genetic flexibility of the variety ($(Y_1 + Y_2)/2$) and the level of stability of the variety yield (CSS, %), the calculation of which is based on the standard variety Nadezhny (taken as 100%), were calculated according to the corresponding methods developed [13–20].

3 Results

The process of creating selection and genetic diversity for effective selection can be carried out on the basis of a careful selection of components for crossing after they have been tested in specific soil and climatic conditions.

As a result of the study of new initial forms of the spring barley collection nursery belonging to different ecological and geographical groups, varietal differences in productivity were revealed (Table 1).

Table 1. Origin, year of zoning, yield and productivity elements of new initial forms of spring barley, 2020-2022.

Variety name	Origin	Year of zoning	Height, cm	Productivity, t/ha				Weight of 1000 grains, g	Spike length, cm	Tillering factor
				$X_i(\overline{XX} \pm SE_{\overline{XX}})$	max	min	C_v , %			
Znatny	Russia	2020	78	6.38±0.52	7.53	5.34	17.1	44.3	8.0	3.0
Pamiati Chepelev		2016	77	5.00±0.48	7.46	3.27	43.4	44.5	7.6	4.0
Kufal	Belarus	2019	73	5.98±0.42	7.38	4.23	26.7	50.0	7.4	3.2
Raider		2019	73	5.03±0.38	6.65	2.97	37.1	50.3	7.5	3.6
KVS Harris	Germany	2019	69	5.50±0.23	6.69	4.90	18.7	47.8	7.9	3.4
KVS Vermont		2019	67	5.74±0.28	7.98	3.90	36.1	44.8	7.4	3.3
Bente		2018	72	4.70±0.18	5.17	4.23	11.4	50.2	8.2	3.7
Ellinor		2020	63	6.02±0.33	6.22	5.81	17.4	44.5	7.1	2.9
LG Nabuco	France	2019	72	4.54±0.26	6.46	3.27	37.0	46.1	7.2	3.6
Rapid		2020	71	5.78±0.32	7.53	4.75	26.3	45.4	7.7	3.9
Laureate	Switzerland	2019	72	4.59±0.17	7.31	1.87	60.1	47.5	6.2	4.4

The maximum yields were obtained in 2022, the minimum - in 2020.

Against the background of contrasting weather conditions during the years of testing, the Russian variety Znatny had the highest average yield - 6.38 t/ha, having an advantage in comparison with German varieties by 5.6-26.3%, French varieties by 9.4-28.8%, Belarusian varieties by 6.3-26.8% and the Swiss variety Laureate by 28.1%. Then come the varieties Ellinor with a yield of 6.02 t/ha and Kufal 5.98 t/ha.

According to the maximum yield obtained over the years of research (7.0 t/ha and more), the studied varieties are located in the following order: KVS Vermont (7.98 t/ha), Znatny (7.53 t/ha), Rapid (7.53 t/ha), Pamiati Chepelev (7.46 t/ha), Kufal (7.38 t/ha) and Laureate (7.31 t/ha).

Variety Laureate was unstable in terms of yield, as being part of the varieties with high indicators of the obtained maximum yield, it had the lowest yield in an unfavorable year for the crop - 1.87 t/ha and the highest coefficient of variation - $CV = 60.1\%$.

As undersized forms from the latest range of varieties, it is recommended to involve in the breeding process new German varieties KVS Vermont and Ellinor, the height of which is in the range of 63-67 cm and changes little over the years of research ($CV, \% = 3.9 \dots 6.0$).

Analysis of the biometric characteristics of the studied varieties showed that the varieties Bente (8.2 cm) and Znatny (8.0 cm) stood out along the length of the ear. All studied cultivars had a slight dispersion for this trait ($C_v, \% < 10.0$), except for Laureate cultivar ($C_v, \% = 10.6$). The most productive bushiness varieties are Pamyati Chepeleva and Laureate - 4.0 and 4.4, respectively. The mass of 1000 grains over the years of our research was characterized by high values - on average from 44.3 to 50.3 g. High grain size (50.0 g or more) was characteristic of the varieties Kufal, Reider, Bente. It has been established that in the year with a large amount of precipitation (2020), the weight of grain per ear and the weight of 1000 barley grains decreased due to lodging of plants. The weight index of 1000 grains of the variety Pamyati Chepeleva, KVS Vermont, Ellinor, LG Nabuko, Rapid and Laureate (less than 40.0 g) was most strongly reduced. Most of the studied varieties had an average variation ($10 \leq C_v, \% \leq 20$) in size, varieties KVS Vermont, Rapid, LG Nabuko and Laureate had a strong variation ($C_v, \% = 22.7 \dots 26.2$).

For a more complete and objective assessment of the adaptive properties of the studied varieties, a number of statistical indicators used to characterize and compare genotypes were calculated (Table 2).

Table 2. Parameters of plasticity, adaptability and stress resistance of spring barley varieties, 2020-2022.

Variety	PUSS, %	C.A.	SF	H _m	d, %	RPV, %	Y ₁ +Y ₂ /2	Y ₁ -Y ₂	Place in the rating scale
Znatny	112.9	1.23	1.41	0.37	0.29	84.7	6.44	-2.19	1
Pamyati Chepelev	26.3	0.92	2.28	0.11	0.56	67.0	5.37	-4.19	10
Kufal	62.7	1.13	1.74	0.22	0.42	81.0	5.81	-3.15	6
Raider	33.5	0.94	2.24	0.14	0.55	75.6	4.81	-3.68	8
KVS Harris	76.6	1.06	1.36	0.29	0.27	82.2	5.79	-1.79	3
KVS Vermont	44.0	1.09	2.04	0.16	0.26	71.9	5.94	-4.08	7
Bente	92.3	0.88	1.22	0.41	0.24	90.9	4.70	-0.94	2
Ellinor	100.5	1.05	1.47	0.35	0.32	96.7	5.22	-1.99	4
LG Nabuco	25.8	0.85	1.97	0.12	0.49	70.3	4.87	-3.19	9
Rapid	60.8	1.10	1.58	0.22	0.37	76.8	6.14	-2.78	5
Laureate	17.7	0.76	3.90	0.08	0.74	62.8	4.59	-5.44	11
Correlation coefficient with yield, r	+0.659	+0.958	-0.509	+0.480	-0.564	+0.502	+0.852	+0.313	-

Increased indicators of the level of yield and plasticity of the variety (PUSS, %) were found in the varieties Znatny and Ellinor (more than 100.0%), lower ones - in the varieties Reider, Pamyati Chepeleva and Laureate (less than 40.0%).

The coefficient of adaptability (C.A.), indicating the ability to stably form higher yields in relation to the selected range of varieties under various growing conditions, indicates a positive response of varieties Znatny, Kufal, KVS Harris, KVS Vermont, Ellinor and Rapid (C.A. > 1.0) to resist the impact of adverse factors that reduce their productivity.

High phenotypic stability (stability factor SF), close to 1.0, is of great adaptive importance. The most phenotypically stable varieties are: Bente (SF=1.22), KVS Harris (SF=1.36), Noble (SF=1.41), Ellinor (SF=1.47) and Rapid (SF=1.58).

A high level of homeostaticity from the new range of varieties is possessed by: Bente, Znatny and Ellinor (Hom > 0.30).

The lower the yield range (d, %), the more stable the object under specific conditions. Under our conditions, the minimum value of the yield range was shown by Bente, KVS Harris, KVS Vermont, Znatny (d, %<0.30).

A valuable indicator for evaluating varieties in various environmental conditions is the realization of their yield potential (RPU, %). Its values are not high in most regions of our country, which is a consequence of both non-compliance with technology requirements and insufficient adaptability of varieties [21]. The highest value of this indicator (more than 80.0%) is cultivars Znatny, Kufal, KVS Harris, Bente and Ellinor.

The ability to form stable productivity in extraordinary environmental conditions can varieties Bente (0.94), KVS Harris (-1.79), Ellinor (-1.99) and Znatny (-2.19), as indicated by the stress resistance index of the variety (U1-U2).

The most productive, with a high correspondence between the genotype and environmental factors, are the varieties Znatny and Rapid (genetic flexibility $(Y1+Y2)/2 > 6.0$)).

To obtain the most complete information for obtaining an effective assessment of adaptability according to the calculated parameters, it is most convenient to use the principle of ranking varieties according to the indicators obtained and to evaluate by the sum of the ranks of each variety (the first rank is the highest). To identify forms with a wide adaptive potential for resistance to biotic environmental factors, the principle of ranking the best varieties in terms of adaptability and ecological plasticity made it possible to single out varieties Znatny, Bente and KVS Harris, which took the first, second and third places in the rating scale, respectively.

An analysis of the correlation dependence of adaptability indicators on the yield of new varieties revealed a significant priority of the contribution of such coefficients as: indicator of the level of variety stability, coefficient of adaptability, level of homeostasis, realization of the yield potential of varieties, genetic flexibility ($r = +0.502...+0.958$).

It should be noted that of all the studied coefficients and indicators, the coefficient of adaptability very closely affects the yield of all the studied varieties of spring barley - $r = +0.958$.

4 Discussion

As a result of the study of new initial forms of the collection nursery of spring barley belonging to different ecological and geographical groups, varietal differences in productivity were revealed - the highest average yield was the variety of the Russian selection Znatny - 6.38 t/ha, having an advantage in comparison with German varieties by 5.6-26.3%, French varieties by 9.4-28.8%, Belarusian varieties by 6.3- 26.8% and the Swiss variety Laureate by 28.1%. New German varieties KVS Vermont and Ellinor distinguished themselves by short stature, the height of which is in the range of 63-67 cm. The varieties Bente (8.2 cm) (Germany) and Znatny (8.0 cm) stood out along the length of the ear. It has been established that the varieties Pamyati Chepelev and Laureate (Switzerland) have the highest productive bushiness - 4.0 and 4.4. The varieties Kufal, Raider (Belarus), Bente were characterized by high grain size (50.0 g and more). According to a number of statistical indicators for assessing adaptability, the following varieties were identified: by increasing the level of yield and plasticity of the variety - Znatny and Ellinor (more than 100.0%); according to the coefficient of adaptability - Znatny, Kufal, KVS Harris, KVS Vermont, Ellinor and Rapid ($K.A. > 1.0$); in terms of phenotypic stability - Bente, KVS Harris, Znatny, Ellinor and Rapid; according to the level of homeostasis - Bente, Znatny and Ellinor; by the minimum value of the range of productivity - Bente, KVS Harris, KVS Vermont, Znatny; for the realization of the yield potential - Znatny, Kufal, KVS Harris,

Bente and Ellinor; in terms of stress resistance - Bente, KVS Harris, Ellinor and Znatny; according to the genetic flexibility of varieties Znatny and Rapid.

5 Conclusion

To achieve competitiveness and improve the economic efficiency of cultivated varieties, one of the most important interests are samples with group traits of adaptability to specific growing conditions. The principle of ranking the best varieties in terms of adaptability and ecological plasticity made it possible to single out the Znatny, Bente and KVS Harris varieties, which ranked first, second and third, respectively, in the rating scale. The use of these varieties, adapted to local conditions, capable of maximizing the potential of productivity in various growing conditions, can increase the stability of the gross harvest of barley grain over the years. Selected varieties are recommended for use in breeding programs to further improve adaptation and stress resistance.

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