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Результаты изучения параметров адаптивности сортов и линий озимого ячменя в условиях юга Ростовской области

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Ячмень – культура многопланового использования, зерно которой может применяться для различных целей. Урожайность ячменя сильно варьирует по зонам возделывания, поэтому для выявления реакции сортов на различные почвенно-климатические условия проводят экологическое сортоиспытание. Новый, более современный и высокопродуктивный сорт обеспечивает рост урожайности, устойчивость посевов к стрессовым факторам, способствует более эффективному использованию природных и антропогенных ресурсов. Создание и широкое распространение в производстве новых адаптивных сортов – перспективный и экологически безопасный путь развития сельского хозяйства. Цель исследования – выявление в ходе конкурсного сортоиспытания наиболее экологически пластичных и адаптивных сортов и линий озимого ячменя в условиях юга Ростовской области. Исследования по оценке пластичности и адаптивности проводили в 2021–2023 гг. на территории Ростовской области. Были изучены 22 образца – сорта и перспективные линии озимого ячменя селекции Аграрного научного центра «Донской». Оценку адаптивности проводили по следующим параметрам: коэффициент экологической вариации, стрессоустойчивость, гомеостатичность, уровень и стабильность сорта, фактор стабильности и селекционная ценность. Выявлены сорта, отличающиеся высокой экологической пластичностью и стабильностью. К стабильным отнесены сорта Степ и Маруся, которые рекомендуется использовать в селекционном процессе как источники высокой стрессоустойчивости, ценности генотипа, низкой вариабельности урожайности. Стабильная урожайность данных сортов обеспечивается за счет комплекса разных его составляющих. Линии Параллелум 2048 и Параллелум 2051 показали себя как пластичные, подверженные изменению урожайности под влиянием внешней среды. В связи с этим для максимальной реализации урожайности указанных линий рекомендовано применять интенсивную технологию возделывания.

Ключевые слова: озимый ячмень, урожайность, сорт, линия, экологическая пластичность, адаптивность, отзывчивость

Results of studying the adaptability parameters of winter barley varieties and lines in the conditions of the south of the Rostov region

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Barley is a multi-use crop whose grain can be used for a variety of purposes. Barley yields vary greatly across cultivation zones, so ecological variety trials are conducted to identify the response of the varieties to different soil and climatic conditions. New, more modern and high-yielding variety provides yield growth, crop resistance to stress factors, contributes to more efficient use of natural and anthropogenic resources. Creation and wide distribution of new adaptive varieties in production is a promising and environmentally friendly way of agricultural development. The purpose of the research is to identify the most ecologically plastic and adaptive varieties and lines of winter barley in the south of Rostov region in the course of a competitive variety trial. Studies to assess plasticity and adaptability were conducted in 2021–2023 on the territory of the Rostov region. 22 samples, varieties and promising lines of winter barley of the Agricultural Research Center "Donskoy" selection, were studied. Adaptability was assessed by the following parameters: coefficient of environmental variation, stress tolerance, homeostaticity, variety level and stability, stability factor and breeding value. Varieties characterized by high ecological plasticity and stability have been identified. The varieties Step and Marusya have been considered stable and are recommended to be used in the breeding process as sources of high stress tolerance, genotype value, and low variability of yield. Stable yield of these varieties is ensured due to the complex of its different components. Parallelum 2048 and Parallelum 2051 lines have shown themselves as plastic, subject to yield changes under the influence of external environment. In this regard, it is recommended to use intensive cultivation technology to maximize the yield of these lines

Keywords: winter barley, productivity, variety, line, environmental plasticity, adaptability, response

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INTRODUCTION

In connection with the observed increase in population growth rates there is a need to increase agricultural production, the basis of which, among other things, is grain farming. For this reason, much attention is paid to the cultivation of winter grain crops all over the world [1]. Barley is one of the most important grain crops not only in domestic, but also in global agriculture [2].

The leading direction of breeding for the near future should be not just the creation of the varieties adapted to growing conditions, but rather obtaining the varieties adapted to the limiting stress factors of the environment of a particular region [3].

Adaptive breeding is the key to solving the problem of optimal combination of high yield, product quality and resistance to environmental stress factors in the variety genotype. High speed and uniformity of germination under stress conditions are vital for obtaining stable yield [4]. The process of developing resistant varieties is continuous as it is impossible to achieve absolute resistance [5]. Barley is an excellent model grain crop for studying adaptive traits, as it is characterized by a high degree of genetic diversity with respect to resistance to stress factors [6]. Information on the general and specific adaptability of new genotypes is necessary for the purposeful selection of new varieties with narrow or broad reaction norms to a specific set of environments [7, 8]. When conducting adaptive breeding, it is necessary to take into account the interaction of the genotype and the environment. Yield growth, increased plant resistance to limiting stress factors of the environment, more efficient use of natural and anthropogenic resources are ensured by creating new adaptive varieties [9]. Obtaining such varieties is the most promising and environmentally safe way to develop agricultural production [10]. Therefore, it is necessary to evaluate breeding material for plasticity and stability traits for the selection of parental forms. The obtained data will help to correctly determine the development potential of barley varieties in specific growing conditions [11, 12].

In this regard, the purpose of the study was to evaluate and identify the most ecologically plastic and adaptive varieties and lines of winter barley in the south of the Rostov region in competitive variety trials.

MATERIAL AND METHODS

The research was conducted by the specialists of the Barley Breeding and Seed Production Department of the Agricultural Research Center "Donskoy" (ARC "Donskoy") from 2021 to 2023. The objects of the study were 22 samples (five varieties and 17 promising lines) of winter barley breeding of the Donskoy Agricultural Research Center, of which three varieties were included in the State Register of the Russian Federation (Timofey, Erema, Marusya), two varieties (Step and Alabai) are under study in the State variety-testing network.

The study was conducted on the experimental fields of the Donskoy Research Center (Zernograd, Rostov Oblast). The area of the survey plot was 10 m²; six repetitions. The variety Timofey, used as a standard, was sown through ten numbers. Peas was used as the forecrop. The soil of the site was ordinary carbonate, thick, warm, temporary freezing through, heavy loamy chernozem. The relief was flat. The soil has a fine-grained structure, loose composition, easy to work, has good air permeability and moisture capacity, is able to accumulate significant reserves of moisture. In general, the soil of the experimental site on fertility, mechanical composition, physical and chemical properties is very favorable for growing crops, including barley. Cultivation technology is the generally accepted one according to methodological recommendations[1] [13, 14].

To determine the indicators of homeostaticity (Hom) and selection value (Sc), the method of V.V. Khangildin and N.A. Litvinenko[2] was used. Stress tolerance (Y_{min} - Y_{max}) and genetic flexibility ((Y_{max} + Y_{min})/2) were calculated according to the equations of A.A. Rosielle and J. Hamblin, as presented by A.A. Goncharenko[3]. The response coefficient to favorable growing conditions (Kp) was determined according to the method of V.A. Zykin[4], the index of variety stability level (VSLI) according to the equation of E.D. Nettevich[5]. Mathematical evaluation of the study results and calculation of the coefficient of variation (V) were carried out according to the field experiment method of B.A. Dospekhov[6].

Weather conditions of the 2020/21 agricultural year were the most unfavorable for the development of winter barley plants. There was an insufficient amount of precipitation in the autumn-winter period: 175 mm fell, which is 102 mm less than the long-run annual average. In June, there was 32 mm more precipitation compared to the long-run annual average (103 and 71 mm respectively). In July, on the contrary, there was a shortage of precipitation (24.6 mm; long-run annual average – 58 mm). In terms of air temperature, the agricultural year 2020/21 was characterized by an increased temperature regime both in autumn and spring-summer periods. The average annual air temperature amounted to 11.7 °C, exceeding the average annual temperature by 2.0 °C. The occurrence of a complex of unfavorable weather factors (abundant precipitation during grain filling and increased temperature regime during the vegetation period of plants) contributed to the spread of leaf diseases, lodging of crops, which led to a shortfall in yield in 2021.

In 2021/22 agricultural year the most favorable conditions for growth and development of winter barley were formed. In winter, 265.7 mm of precipitation fell (long-run annual average – 145.7 mm) in the form of rain and snow. The temperature regime was elevated (+ 3.7 °C to the mean annual temperature), which contributed to favorable overwintering of plants. The minimum air temperature dropped to minus

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10.0 °C. The spring period was characterized by sufficient precipitation (164 mm; long-run annual average – 131 mm). Summer was characterized by minimum precipitation (62 mm; long-run annual average – 129 mm), as well as increased temperature regime: average air temperature in June was 23.2 °C (+ 2.7 °C to the norm), in July – 24.1 °C (+ 1.0 °C to the norm). Such conditions contributed to the start of harvesting in optimal terms.

The autumn-winter period of 2022/23 agricultural year was characterized by a slight decrease in precipitation compared to the average annual values (220 and 277 mm, respectively). However, frequent rainstorms (rainfall – 240 mm, long-run annual average – 131 mm) with wind gusts and hail, observed in the spring period, contributed to significant lodging of crops, which resulted in the formation of low weight of 1000 grains and low yields.

RESULTS AND DISCUSSION

The variance analysis of the results of the two-factor experiment to determine the yield of the studied winter barley samples showed the presence of interaction between the genotype and the environment. The factor "year" had a dominant influence on the formation of yield (98.50%), while the influence of the factor "variety" amounted to 0.87%, and the interaction of these factors was as follows – 0,63%.

During the years of the study, changes in weather conditions were observed, which affected the formation of yields, allowed a more complete assessment of adaptability indicators, as well as the identification of the best varieties and lines. According to the index of environmental conditions, the most favorable conditions for winter barley were in 2022 (Ij = +1,88), less favorable – in 2023 (Ij = –0,54), the most unfavorable was 2021 (Ij = –1,33).

In 2021, the yield of the studied samples was lower than in 2022 and 2023. This indicator ranged from 4.9 (Pallidum 2058) to 6.4 t/ha (Marusya, Step, Parallelum 2019). In terms of the yield, Alabai, Marusya, Step and lines Pallidum 2100, Parallelum 2015, Parallelum 2017, Parallelum 2019, Parallelum 2049, Parallelum 2084, Parallelum 2110, Parallelum 2114, Parallelum 2126, Parallelum 2131 (LSD_{05} = 0.3) significantly exceeded the standard (5.3 t/ha).

In 2022, the highest yields ranged from 8.2 (Parallelum 2049) to 9.6 t/ha (Parallelum 2114) with the standard yielding of 8.5 t/ha. Alabai variety and lines Pallidum 2100, Parallelum 2015, Parallelum 2017, Parallelum 2050, Parallelum 2051, Parallelum 2084, Parallelum 2114 significantly exceeded the standard yields (LSD_{05} = 0,5).

In 2023, the variation in the yield ranged from 4.7 (Parallelum 2048) to 7.9 t/ha (Parallelum 2047) with the standard yield of 6.0 t/ha. Alabai, Marusya, Step and lines Bezosty 2074, Pallidum 1899, Pallidum 2100, Parallelum 2015, Parallelum 2047, Parallelum 2084, Parallelum 2110 significantly exceeded the standard (LSD_{05} = 0.4) (see Table 1).

To calculate ecological plasticity, the linear regression coefficient is an important indicator. During the study period, this indicator varied from 0.73 (Bezosty 2074, Step) to 1.33 (Parallelum 2051). Based on the linear regression coefficient, the following were identified:

1) weakly responsive samples (bi < 1), showing weak response to changes in cultivation conditions: varieties Step (bi = 0.73), Marusya (bi = 0.74), line Bezosty 2074 (bi = 0,73);

2) stably responding to the changes in growing conditions (bi ≈ 1) and able to dynamically change the yield under the influence of variable natural environment: standard variety Timofey (bi = 1.02), lines Pallidum 2100 (bi = 1.00), Parallellum 2084 (bi = 1.02), Parallellum 2047 and Parallellum 2126 (bi = 1,03);

3) responsive (bi > 1): varieties Erema (bi = 1.18), Parallellum 2050 (bi = 1.24), Parallellum 2114 (bi = 1.28), Parallellum 2148 (bi = 1.30), Parallellum 2051 (bi = 1,33).

The standard deviation ranged from 0.01 (Timofey) to 1.52 (Parallelum 2047), which generally characterizes the studied samples as stable samples.

The resistance of the studied samples to stress factors under different environmental conditions was characterized by a smaller dif-

Табл. 1. Средняя урожайность сортов и линий озимого ячменя и их экологическая пластичность
Table 1. Average productivity of the winter barley varieties and lines and their environmental adaptability

Variety, line	Average yield, t/ha			Yi	bi	σ²d
	2021	2022	2023			
Timofey (standard)	5,3	8,5	6,0	6,6	1,02	0,01
Alabai	5,7	9,3	7,5	7,5	1,06	0,34
Bezosty 2074	5,4	8,2	7,7	7,1	0,73	1,34
Erema	5,2	8,7	5,5	6,5	1,18	0,49
Marusya	6,4	8,9	7,4	7,5	0,74	0,04
Step	6,4	8,7	7,1	7,4	0,73	0,10
Pallidum 1899	5,2	8,7	7,7	7,2	0,93	1,06
Pallidum 2058	4,9	8,6	6,0	6,5	1,16	0,05
Pallidum 2100	5,7	9,1	7,4	7,4	1,00	0,21
Parallelum 2015	6,3	9,3	7,0	7,5	0,95	0,03
Parallelum 2017	6,2	9,3	6,0	7,2	1,06	0,39
Parallelum 2019	6,4	8,9	6,3	7,2	0,85	0,16
Parallelum 2047	4,9	8,8	7,9	7,2	1,03	1,52
Parallelum 2048	5,2	8,9	4,7	6,2	1,30	0,91
Parallelum 2049	5,7	8,2	4,9	6,3	0,94	0,66
Parallelum 2050	5,1	9,1	6,0	6,7	1,24	0,02
Parallelum 2051	5,4	9,2	5,0	6,5	1,33	0,87
Parallelum 2084	6,0	9,3	7,0	7,4	1,02	0,02
Parallelum 2110	5,9	9,0	7,4	7,4	0,92	0,48
Parallelum 2114	5,8	9,6	5,7	7,0	1,28	0,51
Parallelum 2126	5,9	9,0	6,2	7,0	1,03	0,19
Parallelum 2131	6,1	8,3	5,9	6,7	0,79	1,42
Ij	–1,33	+1,88	–0,54	–	–	–
LSD_{05}	0,3	0,5	0,4	–	–	–

Note. Ij – index of environmental conditions (characterizes the variability of weather conditions for a particular year of research); Yi – average yield for the years of research; bi – linear regression coefficient (reflects the response of the variety to the changes in growing conditions); σ²d – standard deviation (characterizes the stability of the variety).

ference between minimum and maximum yield (Y_{min} - Y_{max}). The most stress-resistant were varieties Step, Marusya and line Parallellum 2131 (Ymin - Ymax = –2,3; –2,5; –2,4, respectively). Compensatory ability shows genetic flexibility or the response of the variety to growing conditions. The greater the value of the index, the higher the degree of correspondence between the genotype of the sample (variety) and the environmental factors. The highest values were observed in winter barley samples Parallelum 2015 ((Y_{min} + Y_{max})/2 = 7.8), Marusya, Parallelum 2017, Parallelum 2084, Parallelum 2114 ((Y_{min} + Y_{max})/2 = 7.7) (see Table 2).

According to the coefficient of variation, the studied samples had the values in the range of 23.0–51.7%, which indicates their strong variability (≥ 20%). The maximum value was observed in Parallellum 2048 (V = 51.7 %) and Parallellum 2051 lines. (V = 50,5%).

Varieties Marusya and Step had a higher homeostaticity index than other accessions (Hom = 13.5 and 13.6, respectively), indicating their ability to minimize adverse environmental conditions.

High indicators of selection value indicating stable yield and ability to adapt to changing environmental conditions were observed in the varieties Marusya and Step (Sc = 5.5 and 5.4, respectively).

Another equally important indicator for measuring the degree of adaptability of a variety is the coefficient of responsiveness to environmental conditions. According to V.A. Zykin (see footnote 4), the greater the difference between the yield of a variety grown in a favorable environment and the yield of the same variety under unfavorable conditions, the more informative the data will be.

According to the results of the study, all samples responded well to the improvement of the growing conditions. High values of responsiveness coefficient were observed in Parallellum 2048 (Kp = 1.89), Parallellum 2051 (Kp = 1.84), Parallellum 2047 (Kp = 1.79), Pallidum 2058 (Kp = 1.78) and Parallellum 2050 (Kp = 1.76) (see Fig. 1).

Variety stability level index is a complex characteristic that takes into account the level and stability of the yield and reflects the ability of a variety to respond to improved cultivation conditions and, when they deteriorate, to maintain a high level of yield. The higher the VSLI, the more stable the variety. In the conducted study, the level of stability of the yield of the studied varieties varied from 63 (Parallelum 2048) to 206% (Marusya). According to this criterion, the varieties Marusya and Step (VSLI = 206 and 197%, respectively) stood out (see Fig. 2).

Табл. 2. Параметры адаптивности сортов и линий озимого ячменя (2021–2023 гг.)
Table 2. Adaptability parameters of winter barley varieties and lines (2021–2023)

Variety, line	Average yield, t/ha		$Y_{min} - Y_{max}$	$(Y_{min} + Y_{max})/2$	V, %	Hom	Sc
	minimal	maximum					
Timofey (standard)	5,3	8,5	–3,2	6,9	36,2	5,7	4,1
Alabai	5,7	9,3	–3,6	7,5	34,2	6,1	4,6
Bezosty 2074	5,4	8,2	–2,8	6,8	29,7	8,5	4,7
Erema	5,2	8,7	–3,5	7,0	43,2	4,2	3,8
Marusya	6,4	8,9	–2,5	7,7	23,0	13,5	5,5
Step	6,4	8,7	–2,3	7,6	23,0	13,6	5,4
Pallidum 1899	5,2	8,7	–3,5	7,0	35,1	5,9	4,3
Pallidum 2058	4,9	8,6	–3,7	6,8	41,9	4,1	3,7
Pallidum 2100	5,7	9,1	–3,4	7,4	32,8	6,6	4,6
Parallelum 2015	6,3	9,3	–3,0	7,8	29,3	8,6	5,1
Parallelum 2017	6,0	9,3	–3,3	7,7	36,0	6,1	4,6
Parallelum 2019	6,3	8,9	–2,6	7,6	28,7	9,8	5,1
Parallelum 2047	4,9	8,8	–3,9	6,9	39,8	4,7	4,0
Parallelum 2048	4,7	8,9	–4,2	6,8	51,7	2,9	3,3
Parallelum 2049	4,9	8,2	–3,3	6,6	39,0	4,8	3,7
Parallelum 2050	5,1	9,1	–4,0	7,1	43,2	4,0	3,8
Parallelum 2051	5,0	9,2	–4,2	7,1	50,5	3,1	3,5
Parallelum 2084	6,0	9,3	–3,3	7,7	32,3	6,9	4,8
Parallelum 2110	5,9	9,0	–3,1	7,5	29,7	8,0	4,9
Parallelum 2114	5,7	9,6	–3,9	7,7	44,4	4,1	4,2
Parallelum 2126	5,9	9,0	–3,1	7,5	34,7	6,5	4,6
Parallelum 2131	5,9	8,3	–2,4	7,1	28,8	9,7	4,8

CONCLUSIONS

1. Alabai variety and lines Pallidum 2100, Parallellum 2015, Parallellum 2084 had a reliable increase to the standard in the yield in all years of the study.

2. Parallelum 2048 and Parallelum 2051 lines showed themselves as responsive to changes in the cultivation conditions (bi = 1.30 and 1.33, respectively), subject to strong variation under the influence of the external environment (V = 51.7 and 50.5%; Kp = 1.89 and 1.84). Since the yield of these lines varied in accordance with changes in the growing conditions, we recommend them for maximum productivity under intensive cultivation technology.

3. Step and Marusya showed themselves as weakly responsive (bi = 0.74 and 0.73, respectively), stress tolerant ($Y_{min} - Y_{max}$ = –2.5 and

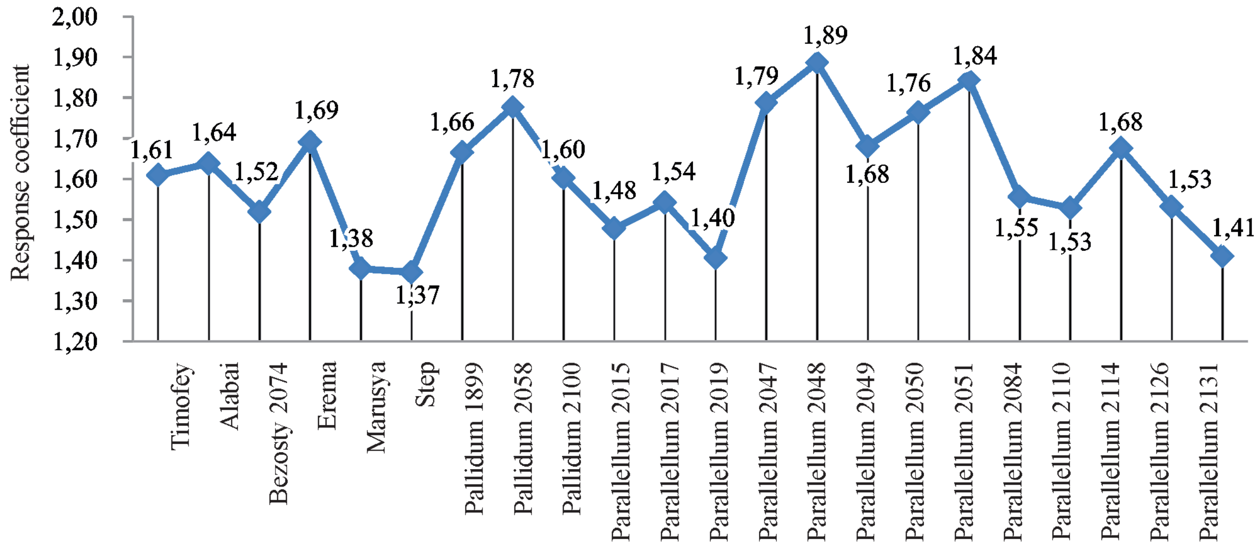

Рис. 1. Коэффициент отзывчивости на улучшение условий выращивания образцов озимого ячменя (2021–2023 гг.)

Fig. 1. Response coefficient to improvement of the growing conditions of winter barley samples (2021–2023)

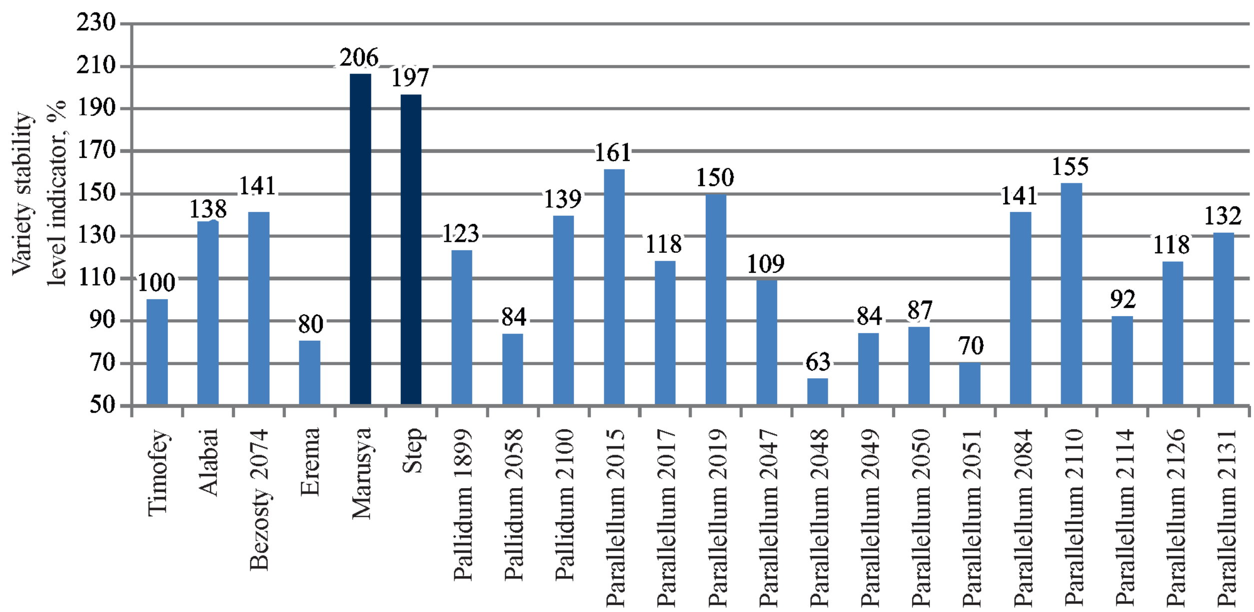

Рис. 2. Показатель уровня стабильности образцов (2021–2023 гг.)

Fig. 2. Sample stability level indicator (2021–2023)

–2.3), adaptive to changing environmental conditions (Sc = 5.5 and 5.4; VSLI = 206 and 197), able to minimize unfavorable environmental conditions (Hom = 13.5 and 13.6). In addition, these varieties showed themselves as genetically flexible ((Y_{min} + Y_{max})/2 = 7.7 (Marusya), 7.6 (Step)). Stable grain yield in these varieties is provided at the expense of different components. In this regard, we recommend using these varieties in the selection process as the sources of high stress tolerance and stability, capable of minimizing the impact of the external environment on the formation of yields.

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