Evaluation of Adaptive Properties of the Spring Barley Varieties Using Mathematical Analysis

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Abstract

Studies on the parameters of ecological adaptability of spring barley varieties in the conditions of Primorsky krai were carried out in 2015-2018 in the Federal State Budget Scientific Institution "Federal Scientific Center of agribiotechnology in the Far East named after A. K. Chaika". New mathematical approaches to solving the problems of selection of parent pairs for crossing, which included selected varieties-sources with high grain weight per plant with ecological plasticity, were considered: Erofey, Harkovsky111, Krinichny, Runis and other. As a result of the released ecologically plastic variety samples, a new source material was developed (Primorsky 153 (Primorsky 44 x Patty), Primorsky 167 (Primorsky 5097 x K-19907 x Runis), Primorsky 184 (Primorsky 5021 x Krinichny), Primorsky 212 (Primorsky 44 x Keystone), which is studied in all parts of the breeding process. The most adaptive variety for Primorsky Krai is Primorsky 184 (Primorets) in 2018, it was transferred to the State Variety Testing.

1 Introduction

Spring barley is the most plastic among early grain crops, with high adaptive capacity to different environmental conditions [1]. According to A. A. Zhuchenko, and A. F. Ursul in favorable conditions, the advantage in cultivation should be given to varieties with high potential productivity, in unfavorable and extreme –to varieties, in which the latter is combined with high environmental sustainability [2].

Development of the grain crop varieties with a sufficiently high and stable yield is one of the important direction of breeding in the Far East [3-6]. When breeding, it is important not only to develop a variety, but also to identify the most favorable zone for its cultivation, in other words, to find an ecological niche [7]. According to E. D. Nettevich, varieties usually correspond to the conditions in which they were developed, since biological properties are always associated with the conditions of selection [8]. At the same time, there are many cases when the crop varieties go far beyond the area for which they were developed. Barley varieties – Priazovsky 9, Acha, Odessa 100, combining high adaptability have a significant distribution area in Russia: Central, Volga-Vyatsky, Central -Chernozemny, North Caucasus, Middle Volga, Ural, West Siberian, East Siberian and Far Eastern regions.

In this regard, the introduction into production of high-yielding varieties of spring barley with high adaptability in the conditions of Primorsky krai is an urgent task.

The goal and tasks of the study are to use mathematical methods that will allow to carry out a more targeted selection for adaptability and develop an environmentally plastic and stable initial material of spring barley for all-round usage (brewing and fodder), meeting modern production requirements (with high productivity, resistant to lodging and resistant to the most harmful fungal diseases) in specific environmental conditions.

2 Materials and Methods

The work was performed in field and laboratory conditions at the Laboratory of breeding of grain and cereal crops at FSBSI "Federal scientific center of agrobiotechnology in the Far East named after A. K. Chaika" in 2015-2018. The objects of the study were six varieties of the competitive variety testing, developed with the participation of source varieties identified by the parameters of adaptability [4, 5].

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Parameters of ecological plasticity of the studied varieties were evaluated using methodics of S. A. Eberhart and W. A. Russell in the presentation of V. A. Zykina [9]. Stress resistance ($Y_{min} – Y_{max}$) was calculated according to A. A. Rossell, J. 2002. Hamblin as presented by A. A. Goncharenko [10].

The stability index (SI), an indicator of stability level of the variety (ISLV) –according to E. D. Nettevich [11] according to formulas 1, 2, the standard deviation (ν^2) and coefficient of variation (V,%) is calculated according to B. A. Dospehov [12] using formula 3, homeostaticity (Hom) and breeding value (Sc 2) – by V. V. Hangildin [13] using formulas 4, 5. Statistical processing of the experimental material was carried out according to B.A. Dospehov [12].

$$ИС = x_{cp} / V\% \quad (1)$$

$$ПУСС = X_{cp} \times ИС \quad (2)$$

$$V = \frac{S}{X} \times 100 ,\% . \quad (3)$$

Variability is considered to be:
a) insignificant if V<10 %
b) average, if V = 10...20 %
c) significant if V > 20 %

$$H_{om} = \frac{x_{cp}{}^{2}}{\upsilon(x_{opt} - x_{\lim})}, \quad (4)$$

where υ is the average kwadro deviation,
x_{opt} is a maximum value of the trait,
$x_{\lim}$ is a minimum value of the trait,
x_{cp} is an average value of the trait.

$$Sc = x_{cp} \times \frac{x_{\lim}}{x_{opt}}, \quad (5)$$

x_{opt} is a maximum value of the trait,
$x_{\lim}$ is a minimum value of the trait,
x_{cp} is an average value of the trait.

3 Results

In breeding work at FSBSI “Federal scientific center of agrobiotechnology in the Far East named after A. K. Chaika” the main method of development a new source material for spring barley is intraspecific hybridization followed by individual selection. The parent forms were selected for the adaptive properties and the ecological-geographical principle by mathematical analysis of quantitative traits, which provide direction in the selection. Into the crossing there were included defined varieties-sources with high grain weight per plant with ecological plasticity: Yerofey, Radical, Nutans 642 and Acha (Russia), Kharkovsky 111 (Ukraine), Gonar (Republic of Belarus), Krinichny (Republic of Belarus), Colter and Orest (USA), Samson, Keystone and Kimberly (Canada), Runis (Mongolia), Patty (France), Marecu, Dorina and Nebi (Germany) [4, 5].

As a result of the selection process with the participation of the studied source varieties the most productive ones were identified: Primorsky153 (Primorsky 44 x Patty), Primorsky 167(Primorsky5097 x-19907 x Runis), Primorsky 184 (Primorsky 5021 x Krinichny), Primorsky 212 (Primorsky 44 x Keystone) which developed high yield in during three years, providing an addition to the standard at the level of 10-20 %.

In the analysis of the obtained lines, which were studied in 2015-2018 in the competitive test, the main economically valuable features were taken into account: productive tillering, ear length, plant height, number of grains per ear, weight of 1000 grains, weight of grain per plant.

The highest yield and its constituent elements were obtained from Primorskiy 184 and Primorskiy 153 varieties, which have a true excess compared to the Primorskiy 98 standard by 1.8 t/ha (Table 1). Variety Primorsky 153 (22.8 pcs.) stood out by the ear grain content.

The adaptability of varieties to environmental conditions, first of all, is judged by the plasticity and stability of their yield, as the most important quantitative trait. Evaluation of samples by parameters of stability and plasticity is possible by studying them in sharply contrasting environmental conditions for several years, which is especially important in Primorsky krai, where during the vegetation period the frequent weather changes limit realization of the potential productivity of varieties, and plants are largely exposed to adverse vegetation conditions, which indicates a wide range of variation, both productivity and other quantitative traits over the years [4].

The stability variance of the trait shows how reliably the variety corresponds to the plasticity which was estimated by the regression coefficient calculated by the formula (6).

$$b_i = \frac{\sum X_y \times I_j}{\sum I_j^2}, \quad (6)$$

where $\sum X_y \times I_j$ is the sum of the yield results

i-th variety for the *j*-th year by the corresponding value of the index of environmental conditions;
$\sum I_j^2$ is the sum of the squares of the index of environmental conditions.

Table 1: Characteristics of spring barley varieties of the competitive testing according to the main economically valuable traits (average for 2015-2018.)

Variety	Hybrid combination	Weight of grain per plant, g	Productive bushiness, pcs.	Reticular Helmintho-sporium teres, %		Number grains in the ear, pcs.
				Currency	Pathogen progression	
Primorsky 98 (st)	(K-19362 Sumerimoti (Japan) x Primorsky 3474) x (K-2938 Shikokunadaka №1 (Japan) x Primorsky 3541)	2.3	1.6	100.0	98.9	17.4
Tihookeansky	[Chernigovsky 90 x (Ussuriysky 8 x Union) x Trebi]	2.7	1.6	100.0	57.5	21.8
Vostochny	Primorsky 6216 x Erofey	2.6	1.7	100.0	75.0	22.5
Primorsky 153	Primorsky 44 x Patty	2.9	2.5	100.0	50.0	22.8
Primorsky 167	Primorsky 5097 x Runis	2.8	1.6	95.0	62.5	21.1
Primorsky 184	Primorsky 5021 x Krinichny	2.9	2.6	80.0	35.5	22.7
Primorsky 212	Primorsky 105 x Kharkovskiy 111	2.7	1.8	100.0	40.0	21.0
The least average difference $_{05}$		0.2	0.1			1.9

Table 2: Adaptive properties of competitive varieties tests of spring barley (average for 2015-2018)

Variety	Yield, t/ha		Ecological stability, Y_{min}-Y_{max}	Coefficient regression, b_i	Variance stability, S^2d_i	Coefficient variations, V %	Index Stability, IS	Indicator of the variety stability level, IVSL	Homeostaticity of the variety, Hom	Breeding value, Sc
	lim	$\bar{X}$								
Primorsky 98 (st)	2,3-4,0	3.2	-1.7	1.8	2.0	20.1	0.0	0.2	3	1.9
Tihookeansky	3,4-4,6	4.1	-1.2	1.6	1.1	17.1	0.2	0.9	18	2.9
Vostochny	3,5-4,7	4.2	-1.2	1.7	1.2	18.1	0.2	0.9	16	2.9
Primorsky 153	3,6-6,1	5.0	-2.5	1.3	4.1	25.6	0.1	0.9	7	3.3
Primorsky 184	4,1-5,7	4.8	-1.6	1.2	2.9	22.4	0.0	0.2	1	3.1
Primorsky 167	3,9-5,2	4.3	-1.3	0.7	1.7	15.9	0.2	1.2	21	2.7
Primorsky 212	2,1-4,7	4.2	-1.6	0.8	1.9	27.6	0.1	0.3	6	1.6

Calculation of the variance of stability (S^2_d) were calculated according to the formula in several stages:

1) First, they find the values of the theoretical yield:

$$X_{ij} = X_i + b_i \times I_j$$

2) Then, determine the deviation of the actual yield from the theoretical formula:

$$d_{ij} = X_{ij} - X_{ij}$$

3) Next, we calculate the variance of the yields stability:

$$\sigma_d^2 = \frac{\sum \sigma_{ij}^2}{(n-2)}$$

where $\sum \sigma_{ij}^2$ is the sum of the squares of deviations of the actual yield from the theoretical;

n is the number of years.

Studies have shown that intensive varieties include: Primorsky 153 (b_i=1,3), Primorsky184 (b_i=1,2), Pacific (b_i=1,6) and East (b_i=1,7) (Table 2). They respond well to the improvement of growing conditions.

To varieties with reduced responsiveness to environmental conditions for yield refers Primorsky 212 (b_i=0,8; S^2d_i=1,9). It is characterized by the lowest regression coefficient (b_i), reliably different from 1 into the smaller side. It responds poorly to changes of environmental factors.

The level of resistance of varieties to stressful growing conditions reflects the difference between the minimum and maximum yield of $Y_{min\text{-}max}$, which has a negative sign. The smaller is the gap between the minimum and maximum crop productivity, the higher is the stress resistance of the variety and the wider is the range of its adaptive capabilities. The higher is the breeding value, the more valuable is the variety, and these varieties have high rates of breeding value.

The most important indicators of adaptive properties are the regression coefficients of yields on the indices of environmental conditions. During the years of the study, the most favorable conditions during the growing season were 2015 and 2018, where I_i (the environment index) was 0.8 and 0.2, respectively. The index of environmental conditions was calculated using the formula:

$$I_j = \left(\frac{\sum X_{ij}}{\upsilon}\right) - \left(\frac{\sum\sum X_{ij}}{l_A l_B}\right)$$

In 2016, there were unfavorable conditions caused by heavy precipitation (389 mm) and the minimum temperature during the growing season, which indicates a negative value (I_i= -0.9). The intersection of the average productivity in the test, which coefficient regression is equal 1, with the yield ordinate which was recovered from the point with the index of environmental conditions, which is always equal to zero, puts the average – 3.8 t/ha (Fig. 1). The regression lines of yield of Primorskiy 184, Primorskiy 153 and Primorskiy 167 varieties are higher than the average point of the test, which is expressed by a higher level of harvest on average over the years of research.

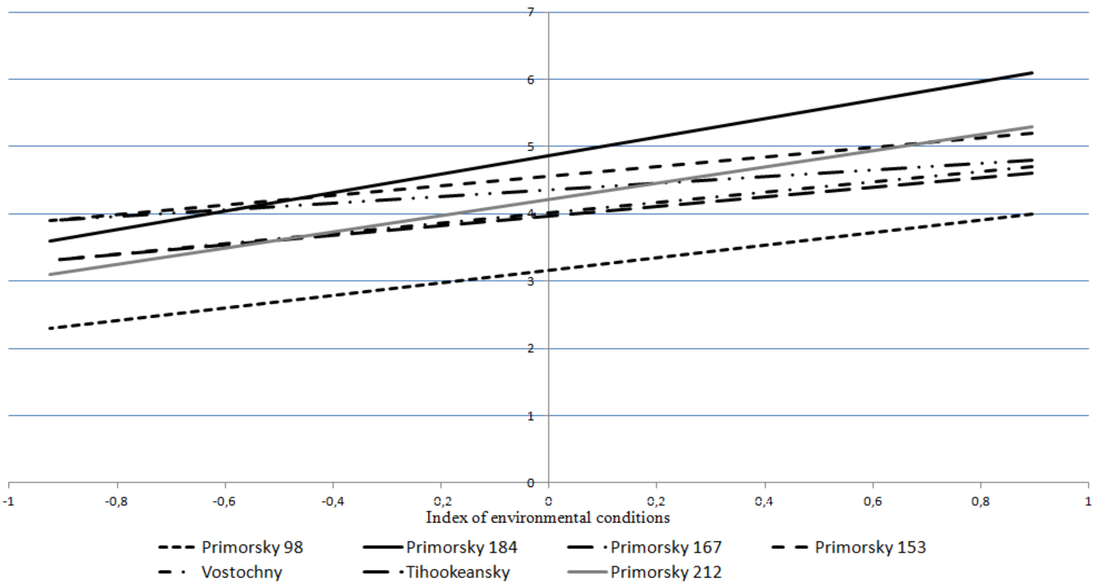

Figure 1: Varieties yield regression lines spring barley to changes of environmental conditions (average over 2015 – 2018.)

In general, the comparison of regression coefficients and stability variance allows to characterize varieties by their response to changing environmental conditions and helps in the selection of varieties for different levels of agricultural production. As a result of researches in the competitive test there were defined the grades which possess high plasticity and stability: Primorsky 153 (Primorsky 44 x Patty) and Primorsky184 (Primorsky5021 x Krinichny).

The zoned varieties Tihookeansky and Vostochny, are characterized by high plasticity, present good results of grain harvest in the conditions of monsoon climate in Primorsky Krai. The varieties can form grain yield more than 4 t/ha in the production conditions.

One of the directions in breeding work with barley is development of varieties of brewing direction. To meet the needs of the brewing industry in the region is largely possible through the production of malting barley in the region. In solving this important problem, the primary role belongs to the variety that is able to form high-quality grain in the appropriate conditions of cultivation.

The most valuable in terms of brewing are large fractions of grain, and the best are malting barley which have a mass of 1000 grains from 37,0 to 48,0 g. The weight of 1000 grains of spring barley varieties ranged from 35.2g. of

Vostochny variety to 43,9 g. of Tihookeansky variety. The research showed that the protein content in grain samples of spring barley in the competitive variety testing varied from 9,8 g. of variety Vostochny to 11.6 g. in variety Primorsky184 and Primorsky212, the starch content varied from 55,2 g. in the variety Primorsky167 to 62,5 g. in the variety Primorsky 98 (Table 3). Filminess of the varieties was in the range of 6.1 to 9.0 %.

Table 3: Biochemical and technological parameters of varieties of spring barley on average for 2015-2018

Variety	Protein, %	Filminess,%	Starch,%	The grain nature, g/l	The mass of 1000 grains, g
Primorsky 98(st)	12.9	9.0	53.4	605	39.3
Vostochny	10.9	8.8	52.6	645	35.2
Tihookeansky	8.6	7.5	54.4	655	43.9
Primorsky 153	11.8	6.9	54.9	640	40.7
Primorsky 184	11.6	6.1	55.7	650	38.4
Primorsky 167	11.4	6.4	59.3	685	43.3
Primorsky 212	11.3	7.4	54.5	635	40.9

As a result of calculating experiments, the method S. Eberhart and W. Russell [6] it allowed to identify the varieties with a low sensitivity of the trait to changes in growing conditions – Primorsky 167 (b_i=0,8-protein; b_i=0.9-starch) and Primorsky 184 (b_i= 0,9-protein; b_i=0.8 for starch). In combination with the increased protein content in the grain, these varieties are of particular value as capable to steadily develop high quality grain in different agricultural conditions (Table 4). Analysis of economically valuable traits of the varieties showed that the most variable characteristics are productivity and filminess.

Table 4: Parameters of ecological plasticity and stability of biochemical parameters of varieties in the competitive variety testing (2015-2018)

Variety	Content								
	Starch's, %			Protein,%			Filminess, %		
	$\overline{X}$	b_i	S^2d_i	$\overline{X}$	b_i	S^2d_i	$\overline{X}$	b_i	S^2d_i
Primorsky 98 (st)	57.9	2.0	0.14	12.5	1.1	31.1	9.0	0.3	1.0
Tihookeansky	60.0	1.5	19.3	11.9	1.4	23.5	7.5	1.3	10.3
Vostochny	59.5	1.4	6.1	12.9	1.7	13.8	8.8	0.9	1.2
Primorsky 153	61.8	0.4	10.5	11.1	1.2	2.0	6.9	1.1	12.2
Primorsky 167	58.2	0.7	0.3	11.4	0.8	16.4	6.4	1.2	2.7
Primorsky 184	58.5	0.8	11.1	12.6	0.9	0.1	6.1	1.6	0.8
Primorsky 212	60.1	1.4	2.7	10.4	1.4	13.5	7.4	1.2	1.7

4 Conclusion

Thus, evaluation of the adaptive capacity and stability of genotypes by methods of mathematical analysis increases the efficiency of the final stage of selection, reduces the possibility of errors in the selection of varieties for transferring them into the State testing. The above results of the use of modern statistical methods indicate the wide possibilities of their use in breeding. As a result of the parameters of adaptability, there were defined varieties by a set of indicators, they are as follows: Primorskiy 153 and Primorskiy 184 (Primorets). In 2018 Primorets was transferred to the State Commission of the Russian Federation for testing and protection of breeding achievements.

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