Estimation of ecological adaptability and stability of the promising winter barley varieties in a competitive variety testing

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Abstract. There has been estimated the ecological adaptability and stability of winter barley varieties in the conditions of the Rostov region. There were studied 4 varieties and 6 lines of winter barley developed in the FSBSI "Agricultural Research Center "Donskoy". The estimation was conducted according to the S.A. Eberchart, W.A. Rassel method (1966, ed. by V.A. Zykin), using a statistical processing software Statistica 10 and Excel. During the years of study (2017-2019), the environmental conditions varied significantly, which allowed reliably estimating the environmental adaptability and stability of the studied varieties and lines. The analysis of adaptability and stability resulted in identification of such responsive varieties as 'Marusya' and 'Yerema', as well as the line 'Parallelum 1976' with linear regression coefficients more than 1. The varieties 'Marusya' and 'Yerema' were the best ones among the studied varieties and lines, showing high and stable productivity over the years of study. According to the study results the variety 'Vivat' showed a sufficiently high level of adaptability. The variety 'Timofey' and the lines 'Parallelum 1979', 'Parallelum 1981', 'Pallidum 1972' showed a sufficiently high level of stability.

1 Introduction

In Russia, the average barley productivity was 2.4 t/ha in 2019, which was 10.0% (0.24 t/ha) higher than in 2018. Over the past 5 years (2014 - 2019), there was a tendency to increase barley productivity on 5.7% (0.13 t/ha). In the Rostov region barley productivity amounted to 2.48 t/ha in 2019, which was higher than the average barley productivity in Russia [1, 2]. In conditions associated with climatic changes through several years, including severe, low-snowy or even snowless winters with insufficient spring moisture accumulation, the variety ecological adaptability is of particular importance [3]. Therefore, in recent years, the farmers have paid great attention to improvement of the adaptability level of the new developing varieties. The analysis of this trait gave an opportunity to predict the variety response to unfavorable environmental conditions, which allowed realizing their potential productivity [4, 5]. According to the above mentioned concept, the current winter barley breeding is aimed at developing the varieties with the improved

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adaptability, high and stable productivity with low energy and resource costs [6, 7]. This direction coincided with the world-wide trend of the grain producing countries to obtain not maximum, but optimal and stable grain productivity over the years [8, 9, 10].

In this regard, the purpose of the current study was to estimate the winter barley varieties and lines according to the parameters of ecological adaptability and productive stability to the environmental changes.

2 Materials and methods

The trials were carried out at the crop rotation fields of the department of barley breeding and seed production at the Federal State Budgetary Scientific Institution "Agricultural Research Center "Donskoy" (FSBSI "ARC "Donskoy") in 2017-2019. The objects of the study were four varieties and six lines of winter barley developed by the FSBSI "Agricultural Research Center "Donskoy". The forecrop was peas. The plot area was 10 m². The number of sequences was 6. The seeding rate was 450 germinating kernels per 1 m². The standard variety 'Timofey' (FSBSI "ARC "Donskoy", RF) was sown through 10 numbers.

The accounts, observations and estimation of the studied varieties were carried out according to the methodology of the State Variety Testing of Agricultural Crops. Mathematical processing of the study results was conducted according to the method of B.A. Dospekhov [11]. Environmental adaptability and stability were evaluated according to the S.A. Eberchart, W.A. Rassel method (1966, ed. by V.A. Zykin), when calculating the theoretical productivity to determine a stability coefficient [12].

Over the study years there was seen a significant variation in weather conditions compared with average multiyear data, which made it possible to thoroughly evaluate adaptability, as well as to identify the best winter barley varieties and lines. In 2016-2017 there was a relatively low moisture supply in the autumn period and an optimal amount in the winter-spring period in comparison with average multiyear data. The agricultural year of 2017-2018 was characterized with a humid winter period (188 mm of rainfall) and insufficient spring moisture (65 mm of rainfall) at the increased average monthly air temperatures. The agricultural year of 2018-2019 was characterized with the precipitation alternations from an optimal amount to an insufficient one throughout the entire period of vegetation at the increased average monthly air temperatures (Figure 1, 2).
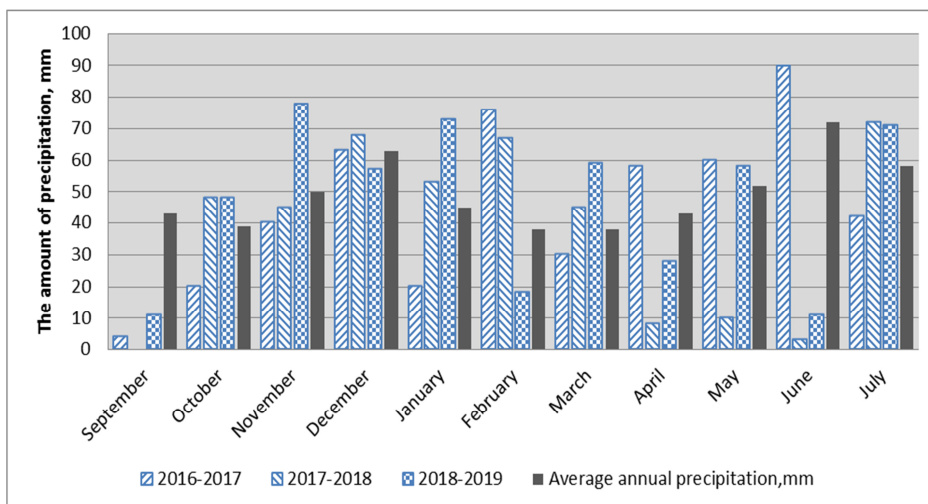

Fig. 1. Average monthly amount of precipitation, mm (weather station Zernograd) in 2017-2019.
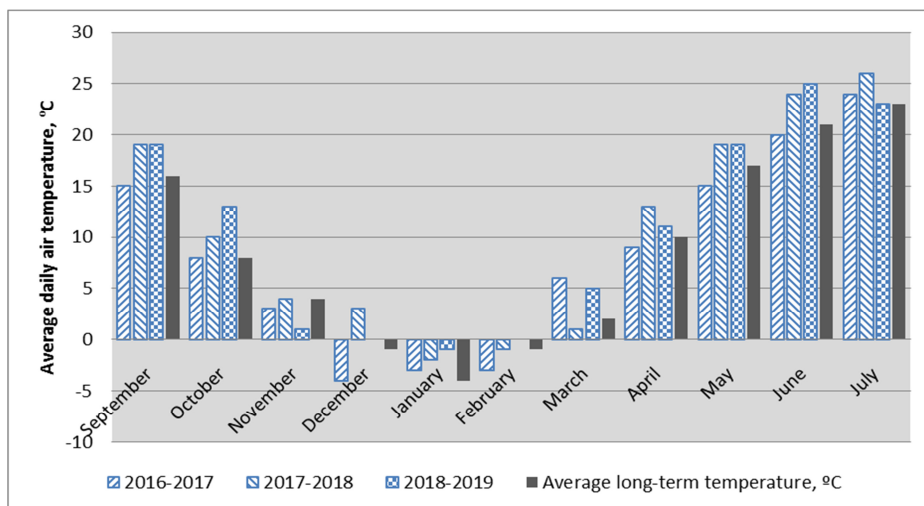
Fig. 2. Average monthly air temperature, °C (weather station Zernograd) in 2017-2019.

3 Result and discussion

In 2017 the varieties' productivity ranged from 9.9 t/ha (the lines 'Parallelum 1979' and 'Parallelum 1981') to 11.4 t/ha (the variety 'Yerema'), compared with 10.0 t/ha yielded by the standard variety 'Timofey'. The productivity of six studied barley varieties and lines significantly exceeded that of the standard one. In 2018 the variety 'Yerema' produced the minimum yield, 8.4 t/ha, and the line 'Pallidum 1972' produced the maximum yield, 10.2 t/ha, while the standard variety produced 8.6 t/ha. During this agricultural year productivity of all studied varieties, except the variety 'Yerema', exceeded the index of the standard variety. In 2019 the variety 'Yerema' produced the minimum yield, 7.1 t/ha, and the maximum 8.2 t/ha was yielded by the line 'Pallidum 1972', while the standard variety 'Timofey' produced 7.6 t/ha. There were only four best winter barley varieties and lines that significantly exceeded productivity of the standard variety. Table 1 has presented the estimation results of productivity and ecological adaptability (bi) of the varieties and lines in 2017-2019.

Table 1. Average productivity of winter barley varieties and lines and their ecological adaptability, 2017-2019.

Variety	Average productivity during the years of study. t/ha					bi
	2017	2018	2019	ΣYi	Yi	
Timofey. standart	10.0	8.6	7.6	26.2	8.7	0.86
Yerema	11.4	8.4	7.1	26.9	9.0	1.52
Vivat	10.6	9.1	7.8	27.5	9.2	1.01
Marusya	11.2	10.0	8.0	29.2	9.7	1.17
Parallelum 1976	10.5	9.0	7.3	26.8	8.9	1.16
Parallelum 1979	9.9	9.1	8.0	27.0	9.0	0.69
Parallelum 1980	10.3	9.3	7.6	27.2	9.1	0.99
Parallelum 1981	9.9	10.0	7.9	27.8	9.3	0.76
Pallidum 1899	10.5	9.4	7.6	27.5	9.2	1.06
Pallidum 1972	10.4	10.2	8.2	28.8	9.6	0.83
ΣYj	104.7	93.1	77.1	274.9	-	-

Y_j	10.5	9.3	7.7	-	9.2	-
I_j	1.30	0.15	-1.45	-	-	-
$SSD_{0.05}$	0.34	0.30	0.31	-	-	-

The variance analysis of the interaction 'genotype-environment' showed that the factor 'year' had 97.5% effect on the varieties' productivity during the study years (2017-2019). Other factors had slighter influence. The factor 'variety' had only 1.3% effect on productivity, the interaction 'variety-productivity' had only 1.2% effect on it. The effects of the studied factors for the obtained data were only of 5% significance.

Over the study years the most favorable growing conditions were in 2017 with an index of environmental conditions (I_j=+1.30), and the most unfavorable growing conditions were in 2019 (I_j = -1.45). The linear regression coefficient (b_i) given in Table 1 demonstrated the change of the winter barley varieties and lines productivity influenced by the growing conditions. This coefficient could be as more or less than 1, and could be equal to 1. When the linear regression coefficient was more than 1 ($b_i > 1$), the variety was highly responsive to the changing growing conditions, which made it more productive when cultivated using intensive technology. Analyzing the obtained data on productivity indices, there were identified two varieties 'Marusya' with b_i = 1.17, 'Yerema' with b_i = 1.52 and the line 'Parallelum 1976' with b_i = 1.16. Figure 3 showed the regression lines of productivity of winter barley varieties and lines, among which the varieties 'Marusya' and 'Yerema' were noticeably distinguished with high productivity at a positive index of the environment.
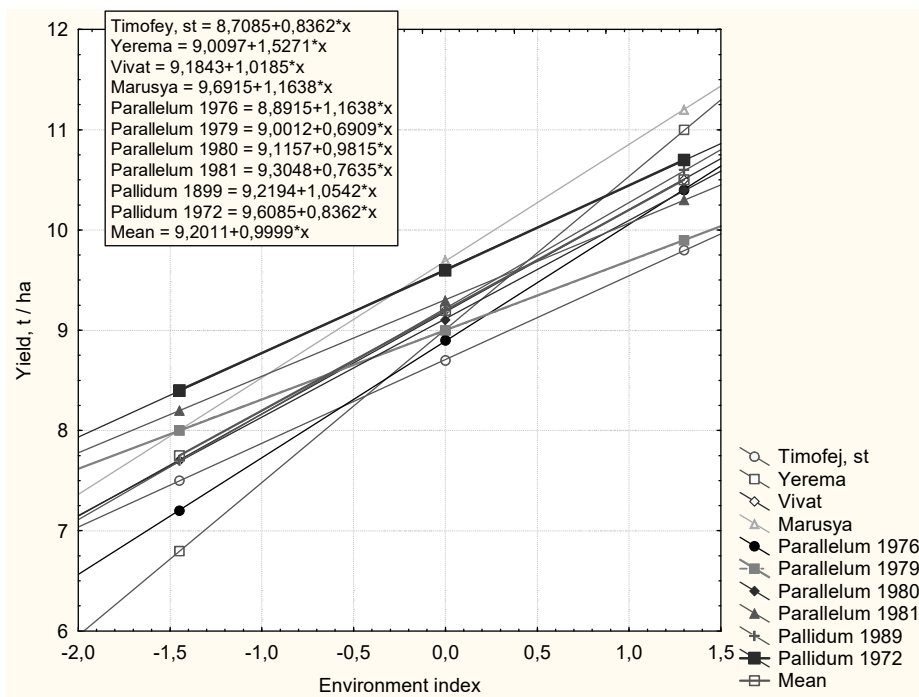

Fig. 3. Regression lines of productivity of winter barley varieties and lines, average in 2017-2019.

During all years of study, the variety 'Marusya' (b_i = 1.17) had the maximum productivity compared to other varieties and lines, which confirmed that he variety was not only responsive, but also stable.

With a linear regression coefficient less than 1 ($b_i < 1$), the variety slightly responded to the changes in growing conditions, allowing it to form stable productivity at unfavorable environmental conditions. These were the variety 'Timofey' with b_i = 0.86 and the lines

'Parallelum 1979' with bi = 0.69, the line 'Parallelum 1981' with bi = 0.76, the line 'Pallidum 1972' with bi = 0.83. These varieties and lines showed poor response to environmental conditions, which characterized them as the most optimal at unfavorable growing conditions.

A linear regression coefficient of the rest varieties ranged from 0.99 to 1.06, which indicated their adaptability. At favorable growing conditions, as well as at the effect of negative conditions, these varieties showed stable productivity. The variety 'Vivat' with bi = 1.01, the line 'Parallelum 1980' with bi = 0.99 and the line 'Pallidum 1899' with bi = 1.06 belonged to the adaptable ones. Based on the obtained data on regression coefficients, there was calculated theoretical productivity and there was shown correlation between the varieties and lines' productivity and their growing conditions over the years of study (Table 2).

Table 2. Theoretical productivity of winter barley varieties and lines and a stability coefficient, 2017-2019.

Variety	Theoretical productivity. t/ha			Deviation of real productivity from theoretical one. t/ha			Stability. $\sigma^2 d$
	2017	2018	2019	2017	2018	2019	
Timofey. standart	9.8	8.8	7.5	0.18	-0.23	0.15	0.11
Yerema	11.0	9.2	6.8	0.42	-0.83	0.30	0.96
Vivat	10.5	9.4	7.7	0.09	-0.25	0.06	0.07
Marusya	11.2	9.9	8.0	-0.02	0.12	0.00	0.02
Parallelum 1976	10.4	9.1	7.2	0.09	-0.07	0.08	0.02
Parallelum 1979	9.9	9.1	8.0	0.00	0.00	0.00	0.00
Parallelum 1980	10.4	9.2	7.7	-0.09	0.05	-0.06	0.01
Parallelum 1981	10.3	9.4	8.2	-0.39	0.59	-0.30	0.58
Pallidum 1899	10.6	9.4	7.7	-0.08	0.04	-0.06	0.01
Pallidum 1972	10.7	9.7	8.4	-0.28	0.48	-0.20	0.34

The data analysis in Table 2 showed that in 2017, at the best growing conditions a large theoretical productivity (more than 10 t/ha) was predicted for 3 varieties ('Yerema', 'Vivat', 'Marusya') and for 5 lines. In 2019, at the unfavorable growing conditions a small theoretical productivity (less than 7.5 t/ha) was calculated for the variety 'Yerema' and the line 'Parallelum 1976'.

The coefficients of stability ranged from 0.00 to 0.96, which generally characterized the studied varieties and lines as the stable ones. The greatest stability was shown by the variety 'Marusya' ($\sigma^2 d$ = 0.02) and the lines 'Parallelum 1979' ($\sigma^2 d$ = 0.00), 'Pallidum 1899' ($\sigma^2 d$ = 0.01), 'Parallelum' 1976 ($\sigma^2 d$ = 0.02). The variety 'Yerema' ($\sigma^2 d$ = 0.96) and the line 'Parallelum 1981' ($\sigma^2 d$ = 0.58) were less stable.

4 Conclusion

The conducted analysis of ecological adaptability made it possible to evaluate the barley varieties and lines of Competitive Variety Testing on responsiveness to environmental changes. The variety 'Marusya' was identified as highly productive and well responsive to a favorable agricultural background. The line 'Pallidum 1972' was characterized with a large and stable productivity, which stated about the prospects for its further study. A high level of adaptability was identified in the variety 'Vivat' and in the line 'Parallelum 1980'.

The variety 'Marusya' and the lines 'Parallelum 1979', 'Pallidum 1899', 'Parallelum 1976' were the most stable ones.

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