

The influence of the climatic potential of Western Siberia on the ecological plasticity of spring barley varieties

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Abstract. Modern technologies of cultivation of crops directly depend on climatic parameters: temperature, amount of precipitation and their distribution by months. Crop productivity can be controlled by studying and understanding the influence of the climatic potential of Western Siberia. This paper is devoted to its features. Analysis of the influence of abiotic factors on the yield of spring barley for the period 2014-2019 showed that: the sum of effective temperatures of 1500⁰C, necessary for the growth and development of plants, accumulates annually; the harvest is formed by atmospheric precipitation for five months (May-September), which is 60% of the average annual norm with fluctuations from year to year from 12.1 to 38.0% (303.6-373.7 mm); the hydrothermal coefficient for May-July has an average effect on the yield of the Abalak, Acha, Vorsinsky 2 varieties (the coefficient of variation of the yield is 11.9, 14.9 and 16.3%, respectively) and significant effect on the crops of the Chelyabinsky 99 variety (the coefficient of variation is 25.7%). The Abalak and Chelyabinsky 99 varieties turned out to be more responsive to changes in growing conditions, as evidenced by the values of the regression coefficient (bi) (1.04 and 1.48) exceeding unity. The Acha and Vorsinsky 2 varieties are characterized by a weak response to improved growing conditions.

1 Introduction

The natural and climatic conditions of Western Siberia are considered to be quite a favorable region for the cultivation of grain crops; spring barley occupies a significant part of the sown area and remains one of the main forage crops [1]. Long-term agronomic practice has shown that the variety is of particular importance in increasing the yield and quality of grain [2]. The success of creating new varieties depends on the study of the source material. For many years, about seven thousand collection varieties of spring barley from different regions of Russia and foreign countries have been studied. The varietal technology and production of food grains and seeds have been improved [3].

The main feature of the Siberian climate is that in some years, meteorological elements are unfavorable for the formation of high quality grain. Due to the short frost-free period and cold wet weather in August, the growing season is longer in some years, and the seeds

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do not have time to ripen, which leads to a decrease in quality [4]. Spring barley needs warm (the sum of active temperatures is above 10°C) from 960-1450°C, depending on the variety.

The development of adaptive varieties that are resistant to various stresses has been and remains an urgent problem, especially since the set of negative factors is expanding due to climate change [5, 6, 7]. Evaluation of varieties in ecological variety testing will make it possible to single out from a large number of created varieties with high potential productivity varieties with the greatest degree of adaptation to the conditions of a particular region [8, 9].

Thus, the issue of crop productivity management does not lose its relevance, especially in the era of climate change.

2 Materials and methods

Objective of the research: to study the influence of the climatic potential of Western Siberia on the ecological plasticity of spring barley varieties.

The data were obtained on the basis of analysis and generalizations of materials from the Yalutorovskiy State Variety Testing Site (SVTS) for 2014-2019.

Four varieties of spring barley included in the register of breeding achievements in 10th (West Siberian) region were studied: Acha, Vorsinsky 2, Chelyabinsky 99, and Abalak (standard).

Agroclimatic indicators by years of research are shown in Table 1.

In Western Siberia (northern forest-steppe of the Tyumen region), there is a wide range of crops suitable for cultivation, which is limited by the total need for heat and the sum of effective temperatures (May-September), which varied over the years of research from 1511.0 to 2520.1°C.

Based on the analysis of the complex indicator of the Selyaninov hydrothermal coefficient (HTC), the studied weather conditions in the northern forest-steppe of the Tyumen region were not the same: 2014, 2015, 2018, and 2019 - wet; 2016 and 2017 - slightly arid.

Table 1. Agroclimatic indicators in 2014-2019, according to the branch of the FSBI “Hydrometeorological Center of Russia” in the Tyumen region.

Indicators	2014	2015	2016	2017	2018	2019
Average annual air temperature, °C	+1.2	+3.4	+3.8	+1.6	+1.1	+2.2
Maximum air temperature, °C	+32.0	+33.3	+31.5	+32.0	+32.1	+31.3
Minimum air temperature, °C	-38.0	-37.7	-34.8	-40.9	-35.3	-40.8
Annual precipitation, mm	522.5	523.0	440.7	392.1	610.8	436.9
The amount of precipitation for the period May-September, mm	303.6	373.7	253.8	253.6	355.2	316.7
Soil freezing depth, cm	104	76	72	69	150	95
Snow depth, cm	47	58	44	54	27	46
The sum of effective temperatures for the period May-September, 0C	2171.4	2249.5	2520.1	2225.5	2164.2	1511.0
Hydrothermal coefficient for the period May-September	1.4	1.6	1.0	1.1	1.6	2.1

The arable land used by the Yalutorovskiy SVTS is occupied by leached chernozems with characteristics and properties typical of Western Siberia. The humus content in the arable layer (0-30 cm) varies from 7.65 to 9.05%, deeper it decreases from 4.41 to 0.72-0.54%. The gross content of nitrogen and phosphorus in the arable layer is 0.43-0.44% and 0.16-0.18%, and their reserves reach 20 and 8.5 t/ha, respectively [10, 11, 12, 13].

The technology of barley cultivation includes: early spring harrowing at the onset of physical ripeness of the soil in 2-3 traces across the direction of the main cultivation; pre-sowing tillage; before sowing - incision ammonium nitrate for the planned yield of 5 t/ha; sowing with a seeding rate of 5.5 million viable seeds per hectare (Table 2); harvesting, which was carried out in the phase of full ripeness by direct combining; plowing for 20-22 cm.

Table 2. Dates of sowing barley, 2014-2019.

Dates of sowing in 2014-2019					
2014	2015	2016	2017	2018	2019
18.05	17.05	16.05	17.05	15.05	19.05

3 Results

In the structure of sown areas (Table 3) of agricultural enterprises of the Tyumen region, barley occupies from 21% (2017-2019) to 25% (2015).

Table 3. Sown area of grain crops, 2014-2019 (according to the Department of the Agro-Industrial Complex of the Tyumen Region).

Sown area, thousand hectares					
2014	2015	2016	2017	2018	2019
144.71	163.87	141.71	136.92	128.30	126.49

Temperature features of May 2014-2019 led to sufficient warming of the soil cover and allowed sowing spring wheat, barley and oats traditionally in the third decade of the month. May 2018 was the coldest of the five years of observation (3.4°C colder than the multiyear average). In June, this dynamics remained, the average temperature was 2.5°C below the norm. July, on the other hand, was dry and hot.

In 2014, the July temperature regime was 3.1°C colder than the norm. These fluctuations were influenced by the course of the phases of development of grain crops, which was reflected in the overall yield.

In the general dynamics of temperature in August 2014-2018, the coldest were 2015 and 2018, in others - the regime was comfortable for grain crops and slightly warmer than the norm: by 1.5°C - 2014 and 2019, 2.9°C - 2016, 0.6°C - 2017

The temperature features of August were not the same.

Another indicator, the sum of effective temperatures, gives more information about the growth and development of grain crops (Table 4). The 1500⁰C required for plants accumulated during all the years of research. However, in 2016, the maximum accumulation of the sum of effective temperatures was noted - 2520.1⁰C, the summer was moderately warm in the first months, hot in the middle, and ended with a sharp cooling at the end of August.

Table 4. Sum of effective temperatures, 2014-2019.

Years	Sum of effective temperatures, °C					
	May	June	July	August	September	May-September
2014	399.9	501.0	455.7	561.1	253.7	2171.4
2015	415.4	600.0	508.4	409.2	316.5	2249.5
2016	372.0	516.0	598.3	660.3	373.5	2520.1
2017	310.0	507.0	545.6	523.9	339.0	2225.5
2018	244.9	432.0	660.3	480.5	346.5	2164.2
2019	96.0	391.0	475.0	320.0	189.0	1511.0
2014-2019	306.4	491.1	540.6	492.5	303.0	2140.3
perennial	378.5	560.8	647.4	575.1	343.6	2505.3

The soil moisture regime depends on the amount of precipitation and their distribution throughout the year. In the northern forest-steppe of the Tyumen region, the average annual precipitation rate is 450.0 mm (Table 5). However, it fluctuates over the years and seasons. For seven autumn-winter-early spring months (October-April), the average annual precipitation is 40% of the annual norm (179.0 mm) with an annual amplitude of 29.0 to 42.0%.

In May-September, the average precipitation is 271 mm (60% of the average annual) with annual fluctuations from 12.1 to 38.0% (303.6-373.7 mm). The harvest is formed by atmospheric precipitation for five months and largely depends on the technical solutions of specialists during this period.

Table 5. Dynamics of precipitation, 2014-2019.

Years	Precipitation, mm					
	average annual amount	on average for 2014-2019,%	to average long-term,%	including May-September	on average for 2014-2019,%	to average long-term,%
2014	522.5	105.0	116.1	303.6	98.5	112.0
2015	523.0	105.0	116.1	373.7	121.3	138.0
2016	440.7	88.5	98.0	253.8	82.4	93.7
2017	392.1	78.8	87.1	88.5	97.9	93.6
2018	610.8	122.7	135.7	355.2	115.3	131.1
2019	436.9	89.6	97.0	281.9	91.5	104.0
2014-2018	487.7	100.0	-	308.0	100.0	-
long-term	450.0	-	100.0	271.0	-	100.0

Maximum atmospheric precipitation - 142.0 mm according to the long-term average indicator (52% of the average for May-September) - falls in July-August. Physical properties of the soil, such as soil density, porosity of aeration and capillary porosity, also play an important role in the formation of spring moisture reserves in the soil [14, 15]. These features of precipitation give reason to recommend programming technological solutions with a more efficient use of this maximum due to the selection of appropriate varieties, optimal sowing times and other methods.

The amount of precipitation in May-June ranged from 53.5 in 2017 (HTC=0.80) to 155.2 mm in 2018 (HTC=4.0).

For the period 2014-2019, 2016 and 2017 were slightly arid; 2014 - fairly humid; 2015 - wet; 2018 and 2019 - perhumid.

The most favorable conditions for the growth and development of the studied varieties were formed in 2014 and 2019. The environmental conditions index was positive: from 0.31 to 0.86; the worst conditions were noted in 2016 - - 0.97 (Table 6).

Table 6. Barley yield, 2014-2019.

Varieties	Years							Plasticity, (bi)	Stability, (σ^2_d)
	2014	2015	2016	2017	2018	2019	average		
Abalak (st)	4.48	3.99	2.91	4.31	3,88	4.84	4.07	1.04	0.06
Acha	3.82	3.63	3.03	3.77	4,06	4.37	3.78	0.69	0.04
Vorsinsky 2	4.69	3.98	3.01	3.58	3,72	4.19	3.86	0.78	0.13
Chelyabinsky 99	3.72	3.79	2.66	3.13	3,77	5.52	3.77	1.48	0.18
Environmental conditions index	0.31	-0.02	-0.97	-0.17	-0,01	0.86			

The linear regression coefficient of the yield of varieties and breeding lines *bi* shows their response to changes in growing conditions. The Abalak (1.04) and Chelyabinsky 99 (1.48) varieties were more responsive to changes in growing conditions; their regression coefficient (bi) was higher than one. The Acha and Vorsinsky 2 varieties had a regression coefficient of less than one, i.e. they are characterized by a weak response to improved growing conditions. Stability (σ^2_d) is an important parameter in the evaluation of varieties and breeding lines. The lower the σ^2_d indicator, the smaller the difference between the theoretical and actual yield, and hence the higher stability of the analyzed feature in time and space. High stability was observed in all studied varieties (0.04-0.18). The reaction of barley varieties to environmental conditions is clearly shown in Figure 1.

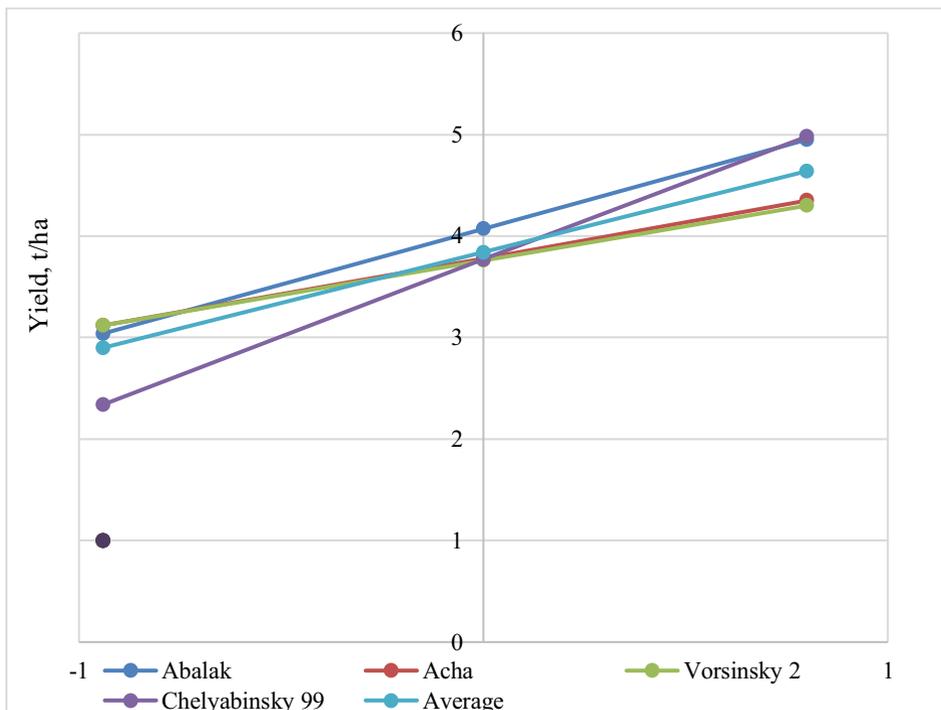


Fig. 1. Regression lines of yield of spring barley varieties, 2014-2019.

The Abalak standard variety has higher yields than the average for the experiment due to the higher average yields over the years of the study. The rest of varieties have regression lines below the average.

The magnitude of the slope of the regression lines provides visual information about the behavior of varieties relative to each other and in comparison with the average response of varieties to changes in growing conditions.

The regression lines of the Abalak variety run parallel to the average for the experiment; this variety changes its yield with changing conditions ($b_i = 1.04$). The Acha and Vorsinskiy 2 varieties are characterized by low responsiveness to the improvement of growing conditions ($b_i = 0.69$ and 0.78 , respectively). The Chelyabinsky 99 is characterized by responsiveness to improved growing conditions, as indicated by the steep regression line. In harsh conditions, the yield of this variety was lower than others in the set, but also has a high average yield. Of the studied varieties of spring barley, Abalak and Chelyabinsky 99 stood out in terms of plasticity and stability.

Correlation and regression analysis showed that the yield of barley has an average and strong dependence on the HTC for May-July (Table 7).

Table 7. Relationship between barley yield and HTC (May-July), and its stability depending on the year.

Variety	Average yield, t/ha	Correlation coefficient	Regression equation	Coefficient, %	
				variation	stability
Abalak	4.07	+0.66	$y=1.11X+2.44$	16.3	83.7
Acha	3.78	+0.83	$y=0.94X+2.41$	11.9	88.1
Vorsinsky 2	3.86	+0.57	$y=0.82X+2.66$	14.9	85.1
Chelyabinsky 99	3.77	+0.97	$y=0.82X+2.66$	25.7	74.3

In the current weather conditions of 2014-2019, the yield of the Abalak, Acha and Vorsinsky 2 varieties changed in an average degree ($V = 11.9$ - 16.3%) and ranged from 3.78 to 4.07 t/ha. The Chelyabinsky 99 variety turned out to be responsive to changes in air temperature and the amount of precipitation ($V = 25.7\%$).

4 Conclusions

Of the studied spring barley varieties, Abalak and Chelyabinsky 99 stood out in terms of plasticity and stability. The Chelyabinsky 99 variety ($V = 25.7\%$) was more responsive to changes in abiotic factors during the years of research.

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