

Agrometeorological characteristics of spring barley in the Northern Trans-Urals

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Abstract. The purpose of this work was to study the effect of air temperature on the duration of the growing season in Western Siberia (Russia). Material and methods: phenological observation of 6 varieties of spring barley (Abalak, Zolotnik Naran, Tandem, DLA-14 and Pasadena) was carried out for the period from 2016 to 2020. The sensitivity of varieties to temperature conditions is determined. The optimal average daily air temperature during the interphase periods was established: shoots-heading 31-35 days, and heading-ripeness 34-37 days. The optimal sums of effective temperatures above 10 °C, necessary for the growth, and development of spring barley varieties, have been calculated. The Abalak variety was distinguished by a narrow temperature range in both interphase periods (the first period - 0.7 °C; the second - 2.3 °C), which indicates a low plasticity of this variety. The agrometeorological characteristic obtained from the data of field experiments can be used to identify the areas of cultivation of varieties, as well as for a scientifically based assessment of the territory in relation to the variety. The optimal, minimum air temperatures for each variety are calculated. The sensitivity of varieties to temperature changes was studied.

1 Introduction

Barley is an important agricultural crop *Hordeum vulgare* L.(1753) Barley occupies about 91 million hectares areas worldwide, and is in fourth place after the main cereal crops (wheat, rice and corn) [2]. In Russia, spring barley is mainly cultivated. It occupies about a third of the world's cultivated area. Spring barley is the most early-ripening and plastic crop, widely cultivated in all zones - from the Arctic to the southern borders of Russia. Large areas of sowing are concentrated in the steppe regions of the South-East, the Central Chernozem zone, the North Caucasus, in the northern regions of the Non-Chernozem zone, Siberia and the Urals.

Depending on climatic conditions, and soil composition the picture of agriculture in Russia, and the types of vegetable plants cultivated in the regions, are changing. Historically, agriculture in Russia has been carried out in extreme conditions. More than 70 % of the territory of Russia is located in either extremely cold or excessively arid climates [1, 4].

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By acting on the intensity of manifestation of environmental factors, it is possible to regulate the growth, and development of plants to a certain extent [2-3]. At the same time, at each stage of plant development, their requirements for environmental conditions, and the role of individual factors are constantly changing. The intensity of the impact of external factors can be weak (insufficient, minimal), most favorable for the growth, and development of plants (optimal), and extremely high (maximum) [5]. The minimum and maximum manifestations of factors should be represented as extremely negative values of the conditions under which plant life is still possible [6]. The reaction of plants to growing conditions, and their resistance to changes in the action of individual factors is quantified by the intensity of photosynthesis and respiration [8].

The influence of meteorological conditions on agricultural plants is enormous. The weather factor is limiting. The growth and development of crops, and their productivity depend on temperatures and rainfall. Each crop has its own needs for heat, light, moisture; and each of them develops under the optimal combination of weather conditions for it. All plants in this zone need moisture, but in moderate amounts, with its excess in the soil, oxygen does not enter the roots of the plants, the breathing process is disturbed and, as a result, their death [7].

Barley is a cold-resistant crop, the sum of the required temperatures is from 1200 to 1800 °C, depending on the precocity of the variety. Barley seeds can germinate at a temperature of 1-20°C. But the best temperature for the appearance of friendly shoots is 15-20 °C. Small frosts (4-5 °C) are tolerated by barley seedlings without any special negative consequences. New high-yielding varieties of adapted to a specific type of meteorological conditions are needed to increase the yield of spring barley. The creation of new varieties is a complex and lengthy process. The solution is to choose from the existing barley varieties the most suitable for a particular soil-climatic zone. To do this, it is necessary to know the agrometeorological characteristics of the variety and zone [12].

In barley (as a grain crop), the following growth phases are distinguished: germination, tillering, tube formation, heading, flowering and ripeness phases: milky, waxy and full. In the period of germination and tillering, intensive use of nutrients occurs: the supply of nutrients exceeds their consumption for the formation of organs [9, 11].

From the phase of entering the tube, intensive growth of the stems occurs - at this time, barley is very sensitive to a lack of moisture [10]. If during this period the soil does not contain the required amount, the ear will not be able to develop normally, and the number of barren spikelets will increase in it, which will invariably lead to a decrease in yield.

Soon an ear begins to form - the mass of the aerial part increases sharply. The root and outlet are gradually depleted, losing the accumulated reserve nutrients. During this period, most of the nutrients go to the formation of grains in the ear.

During the flowering period, stem growth slows down. The leaf surface reaches its maximum development, the supply of nutrients exceeds their consumption for the functioning of a living organism.

Therefore, the boundaries of the growing season for agricultural crops are uncertain. weather conditions, crop variety, soil fertility, sowing time and agrotechnical work.

2 Materials and methods

To increase yields, varieties are needed that are resistant to temperature fluctuations, and suitable for a particular cultivation zone.

Purpose: to study the effect of air temperature on the duration of the growing season, and determine the optimal, minimum and maximum temperature for each variety at which it can grow and develop.

Tasks:

- Determine the correlation between air temperature and the growing season.
- Calculate the minimum and maximum air temperature for each variety.
- Determine the plasticity of varieties.

For temperature characteristics for 5 years of observation of phenological observation of the parameters of spring barley. The following phases are measured in the studied parameters: germination-earing, earing-wax ripeness, germination-wax ripeness. Reserve study in 2016-2020 on the experimental field of the Research Institute of Agriculture of the Northern Trans-Urals (Russia).

To calculate the average air temperature for the interfacial period, we first calculate the value of the average daily temperature, and then divide by the duration and period, we get the arithmetic mean.

To calculate the correlation dependence of yield on meteorological conditions of different periods of the year, the following formula was used:

$$r = \frac{\sum l \times t - \frac{\sum l \times \sum t}{n}}{\sqrt{q \times q_1}} \quad (1)$$

Where l and t are the characteristics under study, l is the duration of interphase periods, t is the average air temperature for the period, n is the number of cases in the sample, q and q_1 for formula 1 determined by formula 2:

$$q = \sum l^2 - \frac{\sum(l)^2}{n}; q_1 = \sum t^2 - \frac{\sum(t)^2}{n} \quad (2)$$

The accuracy of the correlation coefficient (r) is determined by the formula 3:

$$m = \frac{1 - r^2}{n} \quad (3)$$

With a correlation coefficient of >0.85 , the equation of a straight line can be calculated from a graphical representation of the relationship between the duration of the interfacial period, and air temperature. With a correlation coefficient of <0.85 , subjectivity is possible in drawing a direct link, and to exclude its parameters a and b in the straight line equation ($l=a \times t+b$), it is better to determine by the formulas:

$$a = \frac{n \times \sum lt - \sum l \times \sum t}{n \sum t^2 - (\sum t)^2} \quad (4)$$

$$b = \frac{\sum l - n \sum t}{n} \quad (5)$$

Where n is the number of cases, l is the duration of the interfacial period, t is the average air temperature for the period.

The planning of experiments, the laying of experiments, phenological observations, and the analysis of the results obtained were carried out according to generally accepted methods [3] Mathematical processing of yield data was carried out on a computer using the Excel program.

3 Results

Many factors influence the growing conditions of crops. The growth and development of crops, and their productivity depend on temperatures and rainfall. The response of varieties to changes in temperature conditions was ambiguous.

The assessment of the dependence of growth and development rates on the average air temperature for the period was carried out in the periods: shoots - heading, heading - ripeness and shoots - ripeness.

An increase in the average daily air temperature significantly shortened the duration of all interphase periods. Seedlings - heading $r = -0.31 \dots -0.77$, and heading - ripeness $r = -0.50 \dots -0.97$ and shoots - ripeness $r = -0.72 \dots -0.94$ (Table 1). An unequivocal reaction to the change in the average daily air temperature was noted in the variety Naran ($r_1 = -0.77$; $r_2 = -0.74$; $r_3 = -0.84$). In the earing-ripeness period, the varieties Tandem and Pasadena reacted more strongly ($r = -0.97$; $r = -0.84$).

Table 1. Dependence of the rates of development and growth of barley varieties (Y) on the average air temperature during the growing season (X), Tyumen, 2016-2020.

Period	Correlation coefficient ($r \pm S_r$)	Coupling equation
Abalak		
seedlings - heading	-0.41±0.19	$y = -0.71 \times X + 45.52$
heading - ripeness	-0.50±0.17	$y = -0.97 \times X + 54.58$
heading - wax ripeness	-0.72±0.14	$y = 2.07 \times X + 106.73$
Zolotnik		
seedlings - heading	-0.37±0.18	$y = -0.61 \times X + 42.57$
heading - ripeness	-0.58±0.15	$y = -0.64 \times X + 47.58$
heading - wax ripeness	-0.94±0.04	$y = -2.33 \times X + 110.25$
Naran		
seedlings - heading	-0.77±0.13	$y = -1.32 \times X + 55.90$
heading - ripeness	-0.74±0.14	$y = -0.87 \times X + 53.40$
heading - wax ripeness	-0.84±0.10	$y = -4.1 \times X + 143.55$
Tandem		
seedlings - heading	-0.31±0.18	$y = -0.85 \times X + 47.51$
heading - ripeness	-0.97±0.03	$y = -1.19 \times X + 58.89$
heading - wax ripeness	-0.84±0.10	$y = -4.37 \times X + 147.73$
DLA-14		
seedlings - heading	+0.70±0.14	$y = 1.37 \times X + 12.08$
heading - ripeness	-0.61±0.11	$y = -1.42 \times X + 59.57$
heading - wax ripeness	-0.86±0.10	$y = -1.79 \times X + 100.85$
Pasadena		
seedlings - heading	-0.52±0.16	$y = -0.91 \times X + 49.60$
heading - ripeness	-0.84±0.11	$y = -1.16 \times X + 57.39$
heading - wax ripeness	-0.84±0.11	$y = -3.78 \times X + 137.96$

compiled by the authors

The compiled equations for the relationship between the growth rates and development of barley varieties and air temperature made it possible to determine the optimal and minimum duration of interphase periods for each variety (formula 4 and 5). The average duration of interphase periods in years with high yields of varieties was used as optimal, it was 31-35 days (seedlings - heading) and 34-37 days (heading - ripeness). In years with low yields, there can be both long interfacial periods, depending on low temperatures, and short ones, determined by an increased amount of heat (Table 2).

Table 2. The most probable duration of interphase periods in years of high (numerator) and low (denominator) crops of spring barley.

Variety	seedlings – heading	heading – ripeness	heading - wax ripeness
Abalak	35	38	72
	34	36	69
Zolotnik	33	37	71
	31	35	68
Naran	35	39	74
	34	37	71
Tandem	35	40	74
	34	36	70
DLA-14	35	37	71
	33	34	69
Pasadena	36	38	74
	35	36	70

compiled by the authors

The sensitivity of varieties to temperature conditions was assessed by the variability index (x). Varieties Abalak and Pasadena were characterized by weak sensitivity, which had the lowest rates of variability in both interphase periods and for the entire growing season (1.0; 1.15; 1.19 and 1.06; 1.21; 1.11, respectively). Variety Naran reacted more strongly than others to temperature changes ($x = 1.31...1.44$). Varieties Zolotnik, Tandem, and DLA-14 almost unambiguously reacted to the temperature background in the first and second interphase periods (Table 3).

Table 3. Sensitivity of barley varieties to temperature conditions during interphase periods.

Variety	Indicator of variability (x)		
	seedlings – heading	heading - ripeness	heading - wax ripeness
Abalak	1.0	1.15	1.19
Zolotnik	1.15	1.26	1.32
Naran	1.33	1.41	1.44
Tandem	1.15	1.21	1.11
DLA-14	1.15	1.26	1.06
Pasadena	1.06	1.21	1.11

compiled by the authors; * x - the ratio of the duration of the period at min t °C to the duration of the period at max t °C.

The studies carried out made it possible to determine the optimal and maximum development temperatures for each variety in separate interphase periods. The range between the optimal and maximum temperature of growth and development can serve as an indirect indicator of the plasticity of the variety to the conditions of cultivation. Among the studied varieties, the more plastic varieties were Zolotnik, Naran and DLA-14 with a temperature range in the period of germination - heading - 4.7...8.2 °C, in the period of heading - wax ripeness - 3.8 ... 6.7 °C. A narrow temperature range in both interphase periods was different for the variety Abalak (the first period - 0.7 °C; the second - 2.3 °C), which indicates a low plasticity of this variety (Table 4).

Table 4. Optimum and minimum temperatures of the growing season necessary for the development of spring barley varieties, Tyumen 2016-2020.

Variety	seedlings - heading		heading – ripeness	
	opt t° C min t° C	range, t° C	opt t° C min t° C	range, t° C
Abalak	21.2 20.5	0.7	18.1 15.8	2.3
Zolotnik	22.2 17.7	4.7	25.4 18.7	6.7
Naran	17.9 9.7	8.2	19.6 15.8	3.8
Tandem	18.9 16.6	2.3	19.6 16.5	3.1
DLA-14	22.1 17.1	5.0	20.8 16.3	4.5
Pasadena	20.5 16.8	3.7	16.8 12.5	4.3

compiled by the authors

Taking into account the optimal growth and development temperatures during the interphase periods, the optimal sums of effective temperatures were determined for each variety. In general, during the growing season they amounted to 1.220 ... 1.251 °C. An analysis of the temperature regime of the studied oat varieties showed that each of them required not only a certain amount of effective temperatures for its growth and development, but also had features of heat accumulation over time. Most of the presented cultivars were more demanding on heat during the heading-ripening period (590...692 °C) than during the germination-earing period (548...630 °C). The exception was variety DLA-14, in which the need for heat was somewhat higher in the first interphase period (Table 5).

Table 5. Optimal sums of effective temperatures above 10 °C, necessary for the growth and development of barley varieties in the conditions of the Northern Trans-Urals.

Variety	seedlings – heading	heading – ripeness	heading - wax ripeness
Abalak	563	671	1.234
Zolotnik	559	692	1.251
Naran	548	665	1.213
Tandem	555	669	1.244
DLA-14	630	590	1.220
Pasadena	559	681	1.240

compiled by the authors

To increase the yield of spring barley, highly productive varieties of spring barley are needed, adapted to the meteorological conditions of the growing zone.

4 Discussion

In the work of the author S. Mohapatra [9], for spring barley, the dependence of the growing season on the maximum temperature, and the sum of effective temperatures is a limiting factor; a similar situation in the present study at the maximum air temperature reduced the growing season for all samples. The sum of effective temperatures was 1.220 to 1.251 °C, which is confirmed in the research work of F. Panik [10]. O.V. Levakova [8] in

the study notes a positive correlation between the growing season and air temperature, in the presented study, the relationship is negative for all periods of the growing season.

5 Conclusion

An agrometeorological assessment of five varieties of spring barley (Abalak, Zolotnik, Naran, Tandem, DLA-14 and Pasadena) is given. The study examined the duration of interphase periods of spring barley at minimum and maximum temperatures. An increase in the average daily air temperature significantly shortened the duration of all interphase periods. Shoots – earing $r = -0.31 \dots -0.77$, and earing – ripeness $r = -0.50 \dots -0.97$ and shoots – ripeness $r = -0.72 \dots -0.94$. The dependence of growth and development rates of plants on the average daily air temperature has been established. The sensitivity of varieties to temperature conditions has been determined. The studies carried out made it possible to determine the optimal and maximum development temperatures for each variety in separate interphase periods. So for, varieties Zolotnik, Naran and DLA-14 the temperature in the period of shoots – heading was $-4.7 \dots 8.2$ °C, in the period of heading - wax ripeness $-3.8 \dots 6.7$ °C. As a result, the obtained data on the minimum temperature can be used to calculate the indicators of moisture availability of varieties during the growing season.

Distribute varieties into groups, knowing their temperature characteristics. The agrometeorological characteristic obtained from the data of field experiments can be used to identify the areas of cultivation of varieties, as well as for a scientifically based assessment of the territory in relation to the variety.

Acknowledgement

The research was carried by the Scientific Research Institute of Agriculture of the Northern Trans-Urals of the Tyumen Scientific Centre of Siberian Branch of the Russian Academy of Sciences within the framework of the state assignment of the Ministry of Science and Higher Education of the Russian Federation (theme No. FWRZ-2021-0015).

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