https://doi.org/10.26898/0370-8799-2022-6-4
УДК: 633.111;581.13

Тип статьи: оригинальная
Type of article: original

ИЗУЧЕНИЕ МЯГКОЙ ПШЕНИЦЫ ПО СНИЖЕНИЮ ТЕМПЕРАТУРЫ ПОЛОГА В УСЛОВИЯХ АЛТАЙСКОГО КРАЯ

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Представлены результаты исследований в области селекции на засухоустойчивость пшеницы по методу инфракрасной термометрии. Отмечено, что в России данный метод до сих пор не получил распространения. Изучен параметр снижения температуры полога (Canopy temperature depression CTD) среди коллекционных образцов яровой мягкой пшеницы. Эксперимент проведен в Алтайском крае в 2019–2021 гг. У 55 сортов яровой мягкой пшеницы исследованы урожайность, элементы ее структуры и длительность периода всходы – колошение. Температуру полога измеряли при помощи портативного инфракрасного термометра. Определяли CTD как разность между температурой воздуха и температурой полога. Средняя по сортам величина CTD составила 6,1, –0,8 и 2,6 °С в 2019, в 2020 и 2021 гг. соответственно. Достоверное влияние на изменчивость данного признака оказал как фактор год, так и генотип. На протяжении трех лет исследования CTD имел стабильную достоверную взаимосвязь с длительностью периода всходы – колошение (r = 0,27–0,37), а в два года из трех – с урожайностью r = 0,32 и 0,60. В самом засушливом году (2020) CTD положительно коррелировал не только с элементами структуры урожая (r = 0,17–0,48), но и с высотой растения (r = 0,55). Наибольшая величина CTD в среднем за три года отмечена у Алтайской жницы (3,5 °С), Степной нивы (3,6), Бурлака (3,8), Обской 2 (3,9 °С), Лютесценс 360/96, Мерцаны, Александра (4,0 °С) и Лютесценс 208/08-4 (4,4 °С).

Ключевые слова: инфракрасный термометр, пшеница, снижение температуры полога, засухоустойчивость, период всходы – колошение, урожайность

STUDY OF SOFT WHEAT BY THE CANOPY TEMPERATURE DEPRESSION UNDER ALTAI TERRITORY CONDITIONS

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Results of research in the field of wheat drought tolerance breeding by infrared thermometry method are presented. It is noted that in Russia this method is still not widespread. The parameter Canopy temperature depression (CTD) among collection samples of spring wheat was studied. The experiment was conducted in the Altai Territory in 2019-2021. Yield, elements of its structure and the duration of seedling – heading period were studied in 55 varieties of spring soft wheat. The canopy temperature was measured with a portable infrared thermometer. CTD was defined as the difference between the air temperature and the canopy temperature. The average CTD across the varieties was 6.1,-0.8, and 2.6 °C in 2019, 2020, and 2021, respectively. Significant influence on the variability of this trait had both the factor of year and genotype. During the three years of the study CTD had a stable reliable relationship with the duration of the seedling - heading period (r = 0.27-0.37), and in two of the three years - with the yield (r = 0.32 and 0.60). In the driest year (2020), CTD was positively correlated not only with the yield structure elements (r = 0.17-0.48), but also with the plant height (r = 0.55). The highest average CTD value for three years was recorded for Altayskaya zhnica (3.5 °C), Stepnaya niva (3.6 °C), Burlak (3.8 °C), Obskaya 2 (3.9 °C), Lutescens 360/96, Merzana, Alexander (4.0 °C) and Lutescens 208/08-4 (4.4 °C) cultivars.

Keywords: infrared thermometer, wheat, canopy temperature depression, drought tolerance, period seedling – heading, yield

Для цитирования: *Лепехов С.Б., Петин В.А., Валекжанин В.С., Коробейников Н.И.* Изучение мягкой пшеницы по снижению температуры полога в условиях Алтайского края // Сибирский вестник сельскохозяйственной науки. 2022. Т. 52. № 6. С. 36–41. https://doi.org/10.26898/0370-8799-2022-6-4

For citation: Lepekhov S.B., Petin V.A., Valekzhanin V.S., Korobeinikov N.I. Study of soft wheat by the canopy temperature depression under Altai Territory conditions. *Sibirskii vestnik sel'skokhozyaistvennoi nauki = Siberian Herald of Agricultural Science,* 2022, vol. 52, no. 6, pp. 36–41. https://doi.org/10.26898/0370-8799-2022-6-4

Конфликт интересов
Авторы заявляют об отсутствии конфликта интересов.
Conflict of interest
The authors declare no conflict of interest.

INTRODUCTION

Climate change models predict an increase in the air temperature and drought frequency in the future [1]. One way to adapt to a changing climate is to breed drought-tolerant varieties. Selection for tolerance of crops to moisture deficit and heat tolerance is complicated due to the following reasons. Firstly, the complexity of the drought phenomenon itself, which can vary in type, time of occurrence, duration and intensity [2]. Secondly, the complexity of plant resistance mechanisms, which include morphological, physiological, biochemical and anatomical features [3]. The drought tolerance of breeding material is traditionally evaluated by the yield under drought conditions [4]. However, selection based solely on yield complicates selection for drought tolerance, since yield is a very complex trait with low heritability under stress [5]. In this regard, it is important to find new criteria for assessing drought tolerance.

Since the late 1970s infrared thermometry method began to be used to estimate the canopy temperature of various wheat varieties [6]. Canopy temperature reveals the water status of plants, i.e. the balance between water consumption by the roots and transpiration by the leaves. This trait is measured with a portable infrared thermometer or an infrared camera. Most often, it is not the canopy temperature that is measured, but the difference between the air temperature and the canopy temperature (Canopy temperature depression – CTD).

Currently, the method of infrared thermometry is widespread in the world due to its simplicity, speed of evaluation of an individual sample and cost-effectiveness. The relationship between the canopy temperature and the yield has been determined [7] with other morphological and physiological traits [8]. However, this method, despite its advantages, is not widespread in Russia.

The purpose of the research is to study the collection of spring wheat varieties by the trait "canopy temperature reduction", to analyze its variability and relationship with other traits.

MATERIAL AND METHODS

The experiment was conducted in the Altai Territory in 2019- 2021. The material of the study were 55 varieties of spring wheat of different ecological and geographical origin of three groups of ripeness. The sowing was carried out in the first ten-day period of May by SSFK-7 seeder on fallow forecrop in the plots of 10 m^2. The seeding rate was 500 grains/m^2. Harvesting was carried out by Wintersteiger classic harvester. During the vegetation period the date of earing was marked. Yield structure elements were determined according to conventional methods. Vegetation canopy temperature was measured in the phase of milk ripeness in triplicate using an infrared thermometer (UT300C). Measurements were taken on a hot sunny cloudless and windless day at 50 cm above the canopy at an angle of 30º to the plane of the plot. Canopy temperature reduction (CTD) was calculated by the formula:

$$CTD = Ta - Tc,$$

where Ta – air temperature, Tc – canopy temperature.

Statistical processing of the results was carried out by methods of variance and correlation analysis.

The weather conditions of the growing seasons 2019-2021 differed in the amount and distribution of precipitation and average daily temperatures. However, in all three years there was drought during the periods from flowering to full ripeness. The average monthly temperature of July 2019-2021 was almost the same as the average annual value, and the average monthly temperature of August exceeded the average annual value by 1.3-2.4 °C. Precipitation deficit in 2019-2021 was recorded in May (-11 to -23 mm to the norm), in 2019 and 2021 - in July (-22 and -29 mm to the norm, respectively). In 2020, the earing was preceded by precipitation deficit in June (-22 mm to the norm).

RESULTS AND DISCUSSION

Positive CTD value averaged across varieties was observed in 2019 and 2021 (6.1 and 2.6 °C) at air temperatures of 27 and 26 °C, respectively. In 2020, at an air temperature of 31 °C, the CTD value averaged -0.8 °C for the varieties. Thus, in 2019 and 2021 at the time of canopy temperature measurement it was cooler than the air, and in 2020 it was warmer.

The trait "canopy temperature decrease" is largely influenced by weather conditions of the years of the study. At the same time, a significant influence of genotype on variation of this trait was established (see Table 1). The interaction of the factors year × genotype was statistically insignificant.

The following varieties were characterized by the coolest canopy on average for three years: Altayskaya zhnica (3,5 ° C), Stepnaya Niva (3,6), Burlak (3,8), Obskaya 2 (3,9), Lutescens 360/96-6, Mertsana, Alexander (4,0), Lutescens 208/08-4 (4,4 ° C). Significantly less ability to canopy cooling compared to the above genotypes had: Omskaya 41 (0,2 °C), Libertina (1,0), Novosibirskaya 41, Izera (1,5), Ershovskaya 34 (1,6), Grenada (1,7), Ershovskaya 33 (1,8), Stolypinskaya 2 and Quintus (1,9 °C) (see Table 2).

Correlation analysis showed a significant positive relationship between CTD and the yield in 2020 (r = 0.60) and 2021 (r = 0.32). Over three years, CTD was consistently positively correlated with the duration of the sprouting - earing period (r = 0.27-0.37). To the greatest extent, the CTD indicator was associated with morphobiological traits in 2020 (see Table 3).

The first researchers paid attention to a large number of environmental factors affecting CTD. Among these factors soil moisture supply, wind, evapotranspiration, cloud cover, air temperature, relative air humidity, and solar radiation should be listed [9]. In this connection, CTD varies more strongly than other traits [10, 11]. This feature of the trait complicates its evaluation and selection of genotypes with cool canopy under drought and heat conditions.

The positive correlation between CTD and productivity traits is indicated by B. Bahar et al. [12]. Significant correlation between CTD and plant height, between CTD and sprouting - earing period, found in our study, is consistent with previously known patterns [13, 14]. Consequently, high-growing and medium-late varieties have a better ability to cool down and bring the canopy temperature to a more optimal for photosynthesis than low-growing and medium-early varieties.

Since in many studies CTD shows a close positive correlation with yield under drought and heat conditions, this parameter is proposed as a breeding criterion for drought tolerance of varieties [15]. Probably insignificant and average correlation of CTD with yield in 2019

Табл. 1. Результат двухфакторного дисперсионного анализа 55 сортов яровой мягкой пшеницы по CTD (2019–2021 гг.)

Table 1. Result of ANOVA for CTD of 55 spring soft wheat cultivars in 2019-2021

Source of variation	*SS*	*df*	*ms*	*F*	$F_{st\ 0,05}$
Year	3923,0	2	1961,5	595,93	3,00
Genotype	321,6	54	6,0	1,81	1,40
Year × genotype interaction	388,0	108	3,6	1,09	1,30
Residual dispersion	1086,2	330	3,3		

Табл. 2. Генотипы яровой мягкой пшеницы с наименьшими и наибольшими значениями CTD (°C) в 2019–2021 гг.

Table 2. Genotypes of spring soft wheat with the highest and lowest CTD (°C) in 2019-2021

Genotype	2019	2020	2021	On average
Omskaya 41	2,0	–3,4	1,9	0,2
Libertina	3,5	–2,8	2,4	1,0
Novosibirskaya 41	5,0	–2,1	1,6	1,5
Izera	3,7	–1,4	2,1	1,5
Ershovskaya 34	4,3	–1,5	2,0	1,6
Grenada	3,7	–1,5	2,8	1,7
Ershovskaya 33	5,2	–1,3	1,5	1,8
Stolypinskaya 2	5,0	–1,8	2,5	1,9
Quintus	5,2	–2,6	3,0	1,9
Altaiskaya zhnitsa	6,0	1,5	3,0	3,5
Stepnaya Niva	7,4	1,1	3,6	3,6
Burlak	6,3	1,9	3,3	3,8
Obskaya 2	7,4	1,8	2,6	3,9
Lutescens 360/96–6	7,0	0,5	3,3	4,0
Merzana	7,1	1,5	3,5	4,0
Alexandr	8,4	0,7	2,7	4,0
Lutescens 208/08-4	7,4	0,8	4,9	4,4
LSD_{05}	2,4	3,1	1,3	–

Табл. 3. Парные коэффициенты корреляции между CTD и другими морфобиологическими признаками яровой мягкой пшеницы (2019–2021 гг.)

Table 3. Coefficients of correlation for CTD and other morphological traits of spring soft wheat in 2019-2021

Trait	2019	2020	2021
Duration of sprouting - earing period	0,30*	0,37*	0,27*
Plant height	0,26	0,55*	0,24
Productive bushiness coefficient	–0,04	0,17	–0,19
Ear length	0,00	0,48*	–0,13
Number of spikelets in an ear	–0,13	0,42*	–0,12
Main ear grain content	–0,04	0,23	–0,03
Main ear grain weight	0,08	0,30*	0,10
Thousand-kernel weight	0,21	0,20	0,25
Yield	0,05	0,60*	0,32*

* $r > r_{table}$ at $p > 0{,}95$.

and 2021 can be explained by mild character of drought. Thus, the average yields from 2019 to 2021 were 4.12; 2.66 and 4.60 t/ha, respectively.

CONCLUSION

As a result of studying the collection of spring wheat varieties according to the CTD parameter, the varieties characterized by a cool canopy were identified. These include: Altayskaya zhnica, Stepnaya Niva, Burlak, Obskaya 2, Lutescens 360/96-6, Mertsana, Alexander, Lutescens 208/08-4. A significant stable correlation of the studied parameter with the duration of the sprouting - earing period (r = 0.27-0.37), as well as a positive correlation with the yield in two years out of three (r = 0.32 and 0.60) was established. However, instability of the studied trait by years makes it difficult to use in practical wheat breeding.

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Дата поступления статьи / Received by the editors 26.05.2022
Дата принятия к публикации / Accepted for publication 08.08.2022
Дата публикации / Published 27.12.2022