PHENOTYPING OF BREAD WHEAT VARIETIES IN VARIOUS CLIMATIC CONDITIONS:TRICHOMES

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Abstract

The effect of environmental climate factors on the formation of leaf pubescence in 15 stress-resistant wheat varieties selected based on previous experiments studied. The conditions of the two-year field experience in the Tashkent region, Uzbekistan, varied in terms of precipitation; the climate in 2021 was dry, and in 2022 it was humid with high humidity. The difference noted in the number and length of trichomes in relation to the changing climatic conditions of the varieties: a dry and very dry climate in 2021 and a rainy spring with increased humidity in 2022.

It was observed that the contagion of the studied wheat varieties with yellow rust depends on climate change. There are some varieties that were nonresistant to rust disease in the irrigated plot during the dry period of the climate, but they showed moderate resistance in the water shortage plot, i.e., in non-irrigated conditions. A different correlation was determined within the studied conditions among the length, number of trichomes, and damage by yellow rust disease, and productivity.

Keywords: Soft wheat, climate change, arid environment, irrigation, drought resistance, high humidity, leaf pubescence, yellow rust.

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INTRODUCTION

The influence of climate change, high humidity or dry weather, and temperature increases that affect the productivity of crops depends on the adaptability of the variety. Trichomes are considered one of the adaptive morphological traits of plants and are important in plant development.

It is known that the hairs, glands, and husks that form in the epidermal layer of a plant are called trichomes. The structure and shape of trichomes are specific for each plant species, and, depending on their structure, they are divided into three groups: small, large, and granular (3) and their functions can be determined from their structure. Substances released from the body of the plant accumulate in the glandular trichomes. The hairs on the leaves and stems of the plants form felt and appear pale yellow or gray in drought conditions. They mainly serve to reflect light and protect the plant from heat. Sometimes trichomes located on the underside of the leaf, around the stomata, reduce the intensity of transpiration (18). Moreover, along with protection from insects and sand in dusty winds, they can also trap and accumulate spores of pathogens (17).

While the leaf hairs on the edge of the leaves hold the water droplets, the glandular trichomes in the middle part help the water droplets move towards the roots (12). Environmental factors, hormones, transcription factors, non-coding RNA, etc. play an important role in regulating the formation, branching, growth, and development of trichomes (19).

Bread wheat is considered one of the most drought-tolerant agricultural crops, and based on the strong hairiness of the leaves; the drought tolerance of the variety can be assessed. Bread wheat (*T. aestivum* L.) produces unicellular, unbranched leaf hairs, and the thickness and length of this pubescence depend on the characteristics of the variety (8, 10). The use of the method of high-throughput phenotyping on microscopic images of folded leaves allows assessing and distinguishing different genotypes by the length and density of trichomes [17].

Within the framework of the ongoing research, 50 stress-resistant varieties were selected for further research based on the drought resistance index of 201 soft wheat varieties adapted to the climatic conditions of Central Asia (2). The main goal of this article is to study the degree of dependence of the leaf hairiness of soft wheat varieties grown in Central Asia on different climatic conditions and external environmental factors.

MATERIALS AND METHODS

I. Experimental design and materials

Field experiments were carried out in 2021–2022, on the experimental field of the Institute of Genetics and Experimental Plant Biology of the Academy of Sciences of the Republic of Uzbekistan, Tashkent, Uzbekistan (41°22' north latitude, 69° longitude). 23'"E;height 444 m/1457 ft). In 2021, the studies were carried out in two different environments (E-environment), under optimal conditions (irrigated field, E1) and under conditions of water deficit (non-irrigated conditions, E2). In 2022, the studies were also conducted under two conditions. However, this year each condition was split into two experiments: the first, under irrigated conditions, plants were grown from seeds obtained under optimal conditions (E3) and under conditions of water deficit (E4) since 2021. The second, under non-irrigated conditions, plants were grown from seeds obtained under optimal conditions (E5) and obtained under conditions of water deficit (E6) in 2021 (Fig. 1). Experiments were carried out on plots of 1 m^2 for each variety.

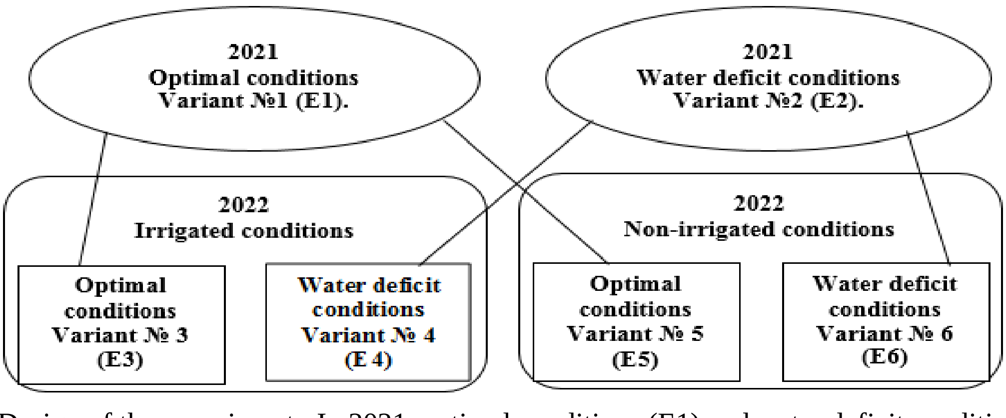

Figure 1: Design of the experiment. In 2021, optimal conditions (E1) and water deficit conditions (E2); in 2022, irrigated conditions from the seeds under optimal conditions (E3) and from the seeds under water deficit conditions (E4) from 2021; and non-irrigated conditions from the seeds under optimal conditions (E5) and from the seeds under water deficit conditions (E6) from 2021.

The objects of the experiment were 15 varieties from various ecological and geographical countries of Central Asia: varieties Bayandi, Raminal, Krasnovodopod 210, Sapali, Shapagat, and Maira from Kazakhstan; varieties Ok Marvarid, Andijan-4, Durdona, Ezoz, and Pakhlavon from Uzbekistan; Grom and Vassa varieties from the Russian Federation; varieties Dank (spinous) and Dordoi-16 of Kyrgyz selection.

II. Assessment of climate variability

Formula: The hydrothermal coefficient (HTC), described by Selyaninov, is a characteristic of the level of moisture in the area and is calculated using the following

$$HTC = \frac{R * 10}{\sum t}$$

Here R is the sum of total precipitation in millimeters for a period with a temperature above +10 ^{0}C, and $\sum$t is the sum of temperatures for this period in degrees Celsius (^{0}C) (20).

The climate of Uzbekistan is acutely continental, and when Selyaninov's Hydrothermal Coefficient (HTC) was analyzed (15) for the years 2021 and 2022, it was observed that the climate in 2021 was dry, and in 2022, due to frequent rains, the humidity was high.

III. Measurement of leaf pubescence

In order to analyze the quantitative characteristics of leaf hairiness of wheat varieties belonging to a selection of different geographical zones, five samples taken from the first leaf under the flag leaf of each variety during the heading period. The process of studying trichomes from leaves conducted according to the methodology of Doroshkov et al. (6). The preparations studied and photographed under a NLCD-307V binocular microscope. Every image uploaded to the LH Detect software, and the number (tpi-trichome per image) and length of trichomes in the image obtained by the microscope lens taken in pixels and converted to micrometers (µm) through the converter. Data from each cultivar (15 dates from 15 fragments on each cultivar) were statistically analyzed.

IV. Damage by yellow rust disease

Yellow rust disease in the studied wheat varieties assessed according to the manual by Koyshibayev (14).

Statistical analysis: Correlation analyses conducted among the number and length of trichomes with climate change, with the damage caused by yellow rust disease, and with the crop yield.

RESULTS

Hydrothermal Coefficient

Hydrothermal coefficients showed 2.93 and 5.41 in March, 0.67 and 0.15 in April, 0.15 and 0.65 in May, and 0.00 and 0.39 in June for the years of the study, respectively (Table 1). Based on the HTC indicators, the climate in 2021 was determined to be dry in April and very dry in May and June under the conditions of Tashkent, Uzbekistan. The climate in 2022 was determined to be rainy with very high humidity (Fig.2).

Table 1 Hydrothermal Coefficient (HTC) during the vegetative period of wheat in 2021-2022 in Tashkent.

HTC	March			April			May			June		
	I	II	III	I	II	III	I	II	III	I	II	III
2021	0,54	5,75	2,8	1,94	0	0,36	0,13	0	0,3	0	0	0
2022	1,66	14,28	0,27	0,02	0,14	0,29	0,89	0,17	0,86	0	0,78	0

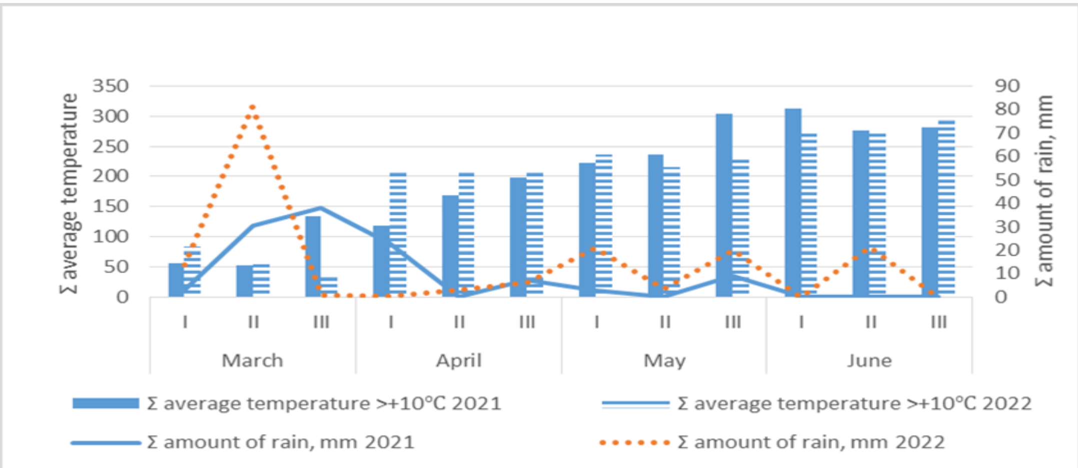

Figure 2 hydrothermal coefficients during the season of wheat in 2021–2022 in Tashkent

The number and length of trichomes

According to the data presented in Fig. 3, on the average statistics of the number and length of trichomes, in 2021, it was determined that the number of trichomes was higher in the optimal condition (E1) compared to the water deficit condition (E2), but the trichome length was almost the same in the optimal condition (E1) and the water deficit condition (E2). In 2022, under high humidity conditions, the number of trichomes in the non-irrigated conditions (E5, E6) was higher than in the irrigated conditions (E3, E4), and the trichome lengths were relatively close to each other. However, in the dry climate of 2021, the trichomes of almost all soft wheat cultivars were better developed than in the climate with higher humidity in 2022.

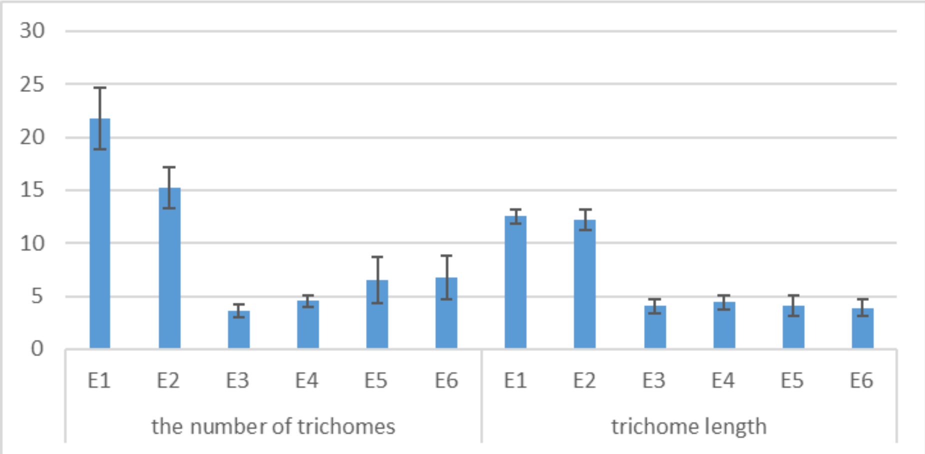

Figure 3 Development of trichomes' dependence on climate change

The trichomes of the studied bread wheat cultivars were analyzed depending on different climatic conditions (Fig.4). According to our data, under optimal conditions, a high density of trichomes was detected in the varieties Krasnovodopod 210, Durdona, Shapagat, Raminal, and Pahlavon. The number of trichomes in other variants of the experiment was significantly less than in the control. At the same time, the number of trichomes was higher in the varieties Grom, Ok Marvarid, Sapaly, and Durdona under simulated drought conditions than in the same cultivars under optimal conditions.

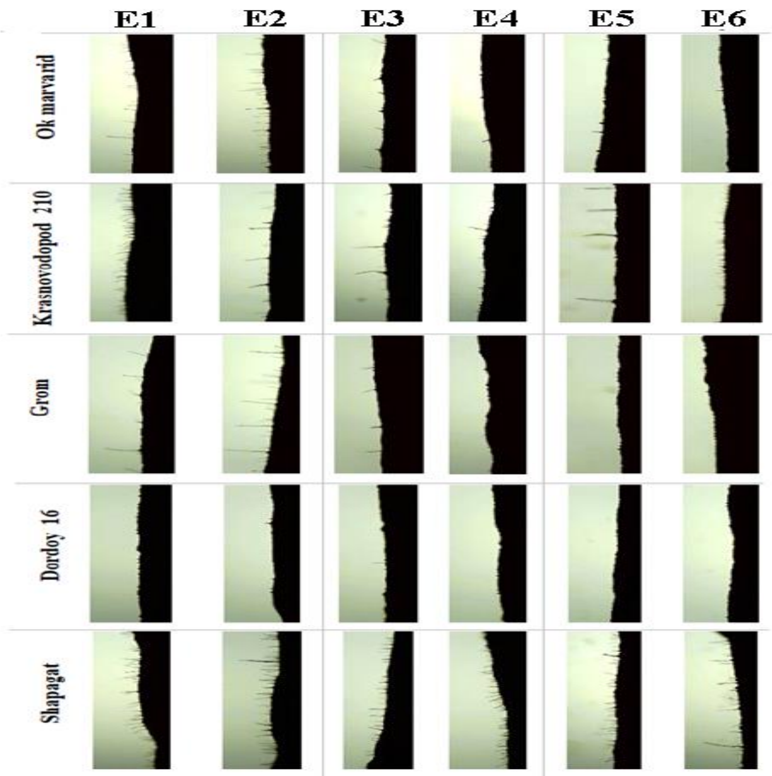

Figure 4. Dependence of the growth of trichome in soft wheat varieties on climate variability

It should be noted, that the variety Dank (awned) differs from other varieties in that the number of trichomes on the leaf surface in variants E2, E5, and E6 exceeds the values in the control (Table 2). In variety Shapagat, the quantitative indicators of trichomes in these variants were close to variant E1. The length of trichomes in the studied varieties also varies in different variants of the experiment. In cultivars Krasnovodopad 210, Grom, Sapaly, and Ezoz, under drought conditions, the length of trichomes significantly exceeds the indicators under the optimal background. Of particular note is the Shapagat variety, in which the length of trichomes under drought conditions is close to the control, while in variants E3 to E6, their length significantly exceeds the indicators under the optimal condition. A tendency for a decrease in the length of trichomes was observed in the other varieties under these variants according to the obtained data on the number and length cultivation conditions.

Yellow rust

The relation between yellow rust damage in soft wheat cultivars and climate variation was determined from the experiments (Table 3). The varieties Bayandi, Sapali, and Shapagat were less resistant to rust disease in the irrigated conditions during the dry period of the climate, but they were moderately resistant in the water deficit conditions, i.e., under non-irrigated conditions. The number and length of trichomes of the varieties Bayandi and Shapagat decreased under water deficit compared to optimal conditions. On the contrary, it was observed that the length of trichomes of the variety Sapali doubled under water deficit conditions. The varieties Ezoz, Wassa, and Maira were found to be resistant to rust diseases under optimal and high humidity conditions, while moderate resistance was observed under water-deficit conditions. The number of trichomes of these varieties was lower under water deficit conditions than in optimal conditions. However, the length of trichomes of this variety was longer under water-deficit conditions. In conditions with high humidity, the varieties Vassa and Maira were without trichomes, whereas in the variety Ezoz there were tiny and sparse trichomes.

Correlation analyses

When the trichome length of bread wheat varieties was observed under different climatic conditions, a strong correlation was observed under stress conditions, while there was a moderate correlation under optimal conditions. A strong correlation was also observed among the number of trichomes themselves, as well as between the number and length of trichomes. Between optimal conditions and high humidity conditions, the number of trichomes and trichome length had a weak correlation, while a moderate correlation was observed between water deficit and high humidity conditions.

The correlation between trichome length, number, and susceptibility to yellow rust disease was weak under optimal conditions, while the correlation under stress conditions was moderate. A negative-moderate correlation was observed between yield and the number and length of trichomes under almost all conditions.

Table 2. Influence of growing conditions on the number and length of trichomes of the studied varieties

		The number of trichomes						Trichome lenght					
		E1	E 2	E3	E4	E 5	E 6	E1	E 2	E3	E4	E 5	E 6
1	Bayandy	13	5	-	6,50	3,80	-	17,8	6,5	-	6,50	7,20	-
2	Raminal	11	13	-	7,80	-	-	21	22	-	4,80	-	-
3	Krasnovodopod 210	62	9	6,70	5,40	1,80	2,50	12,5	22	6,20	6,60	6,80	4,20
4	Grom	8,67	14,33	4,30	1,20	4,10	2,40	18,5	20,4	3,40	1,40	1,30	1,10
5	Sapaly	5,33	9	-	3,40		1,20	11	23,1	-	2,30	-	1,40
6	Ok marvarid	14,67	30,67	4,80	3,60	2,30	1,40	13,5	13,2	5,20	2,40	1,60	1,40
7	Andijan 4	7,67	8,2	-	-	-	3,80	17,2	5,4	-	-	-	2,30
8	Vassa	8,67	2,5	-	4,20	-	5,20	14,7	1,3	-	8,30	-	3,90
9	Durdona	19	40,67	4,50	4,10	2,50	5,40	9,2	9,5	5,20	1,70	0,70	3,40
10	Ezoz	5,7	8	3,50	4,80	2,80	4,80	7,5	16,5	6,80	6,50	2,40	7,20
11	DANK (остистый)	7	8,2	7,60	6,40	14,16	11,20	14	11,5	10,60	6,20	14,50	9,20
12	Dordoy 16	15,2	6,9	2,10	3,40	-	-	1,2	1,1	3,50	0,80	-	-
13	Shapagat	65,2	54,2	16,80	17,50	65,70	63,80	15,4	13,8	18,60	18,70	26,70	24,50
14	Pahlavon	68,00	11,00	-	-	-	-	9,12	10,58	-	-	-	-
15	Maira	15,4	7,8	4,30	-	-	-	5,4	6,2	1,30	-	-	-

Table 3 The degree of morbidity with pathogens of the studied wheat varieties under different growing conditions.

		Yellow rust						Cereal leaf beetle %						Aphids						Mildew %					
		E1	E2	E3	E4	E5	E6	E1	E2	E3	E4	E5	E6	E1	E2	E3	E4	E5	E6	E1	E2	E3	E4	E5	E6
1	Bayandy	S	MS	MS	MS	S	MS	20	0	10	5	30	40	3	4	2	4	1	0	0	0	20	0	50	10
2	Raminal	MS	MR	R	MR	MR	MR	10	0	5	10	20	20	3	2	2	2	2	2	0	0	40	40	60	20
3	Krasnovodopod 210	MR	R	R	R	MS	MR	10	0	5	5	10	10	4	0	2	2	1	1	0	0	20	20	20	20
4	Grom	MS	MS	R	MR	MR	MS	10	20	0	0	20	10	4	2	2	3	0	1	0	0	10	20	40	30
5	Sapaly	S	MS	R	MR	MS	S	30	10	30	5	10	10	4	3	2	2	1	2	0	0	10	30	40	60
6	Ok marvarid	MR	MR	MS	MR	MR	MS	10	0	10	5	20	10	2	0	1	2	1	1	0	0	40	20	20	40
7	Andijan 4	MS	MS	R	R	MR	MR	30	0	5	5	10	10	4	4	1	1	1	1	0	0	5	20	40	40
8	Vassa	R	MR	R	R	R	R	10	0	5	20	5	5	3	1	1	1	1	1	0	0	10	10	5	5
9	Durdona	MS	MR	MR	MS	MS	MR	10	10	20	10	5	5	4	3	1	1	1	1	0	0	5	5	10	5
10	Ezoz	R	MR	R	R	MS	R	40	10	5	5	5	10	3	3	1	1	1	1	0	0	30	20	5	20
11	DANK (остистый)	MS	MS	R	MS	MS	MS	0	0	10	5	20	5	2	3	1	1	1	1	0	0	40	30	10	30
12	Dordoy 16	MR	MR	MR	MR	MR	MR	50	0	5	5	5	5	3	0	1	1	1	1	0	0	10	10	20	20
13	Shapagat	S	MR	MS	MS	MS	MS	30	0	0	5	5	5	3	0	1	0	1	1	0	0	5	20	10	20
14	Pahlavon	MS	MS	R	R	MR	MR	10	4	0	0	5	10	3	1	1	2	1	1	0	0	10	10	40	10
15	Maira	R	MR	R	R	R	R	0	0	5	5	5	5	2	1	1	1	2	1	0	0	30	30	30	30

Table 4 Correlation analyses of the results

		Length of trichome						**Number of trichome**					
		E1	*E2*	*E3*	*E4*	*E5*	*E6*	*E1*	*E2*	*E3*	*E4*	*E5*	*E6*
Length of trichome	*E1*	1											
	E2	0,40	1,00										
	E3	0,48	0,72	1,00									
	E4	0,35	0,60	0,71	1,00								
	E5	0,48	0,72	0,87	0,85	1,00							
	E6	0,47	0,73	0,85	0,84	0,99	1,00						
Number of trichome	*E1*	-0,08	0,09	0,01	0,30	0,19	0,17	1,00					
	E2	0,14	0,14	0,17	0,20	0,08	0,05	0,35	1,00				
	E3	0,40	0,68	0,96	0,76	0,86	0,84	-0,02	0,16	1,00			
	E4	0,37	0,47	0,70	0,93	0,84	0,84	0,31	0,12	0,73	1,00		
	E5	0,46	0,55	0,86	0,85	0,92	0,89	0,23	0,10	0,88	0,85	1,00	
	E6	0,42	0,64	0,87	0,83	0,94	0,96	0,13	0,10	0,91	0,87	0,91	1,00
Damage with yellow rust	*E1*	0,15	0,44	0,12	0,35	0,36	0,31	0,48	0,25	0,15	0,15	0,36	0,20
	E2	-0,19	0,06	-0,18	-0,09	0,07	0,02	0,45	0,08	-0,14	-0,18	0,07	-0,06
	E3	0,19	0,59	0,41	0,54	0,51	0,46	0,14	-0,18	0,40	0,44	0,49	0,35
	E4	-0,01	0,54	0,46	0,60	0,53	0,47	0,23	-0,03	0,51	0,42	0,62	0,44
	E5	0,05	0,27	0,30	0,50	0,36	0,31	0,10	0,28	0,42	0,41	0,51	0,40
	E6	0,00	0,31	0,27	0,37	0,38	0,30	0,33	0,34	0,29	0,24	0,46	0,25
Crop capacity	*E1*	-0,08	0,16	-0,32	-0,28	-0,26	-0,15	0,04	-0,15	-0,32	-0,32	-0,45	-0,19
	E2	-0,43	-0,37	-0,57	-0,44	-0,45	-0,38	-0,06	-0,37	-0,52	-0,42	-0,57	-0,37
	E3	-0,02	-0,16	-0,44	-0,12	-0,26	-0,31	0,15	-0,24	-0,43	-0,23	-0,21	-0,41
	E4	-0,20	-0,20	-0,54	-0,42	-0,43	-0,38	0,01	-0,42	-0,53	-0,45	-0,45	-0,41
	E5	0,10	0,31	-0,28	-0,22	-0,20	-0,16	-0,25	-0,25	-0,19	-0,29	-0,32	-0,20
	E6	-0,60	-0,53	-0,64	-0,33	-0,41	-0,40	0,38	-0,44	-0,62	-0,22	-0,37	-0,42

DISCUSSION

The experiments were conducted in six conditions, and these conditions, i.e., optimal conditions (E1.) and water shortage conditions (E2) in 2021, as well as the four conditions in 2022 with a high humidity climate, are considered sufficient options to show stress resistance and stability of the varieties. Climate variability affects leaf hairiness differently. Due to high humidity, a decrease in the turgor of cells that form leaves and osmotic pressure can negatively affect the development of long trichomes (7).

According to the information presented in the literature, the presence of trichomes on the leaves prevents the development of various pests, especially aphids. The reason for this is that the thickness of the hairs, i.e., the cuticle between the leaves, prevents the development of aphids and slows down their population growth (16). However, when analyzing the number and length of trichomes in the studied varieties, as well as the level of infestation by aphids, it was noted that in dry periods of climate, they developed more than in climates with high humidity. Leech Cereal leaf beetle, on the contrary, develops widely in conditions of high humidity but is not observed in a dry climate. Trichomes synthesize and accumulate flavonoids, a natural plant defense product against harmful insects [1]. The selection of varieties with a high density of trichomes and a low density of leaf stomata helps prevent diseases that cause leaf spots (11).

While studying the leaf hairiness of the 12 varieties of wheat, it was detected that the average length of trichomes in hexaploids varied from 30 to 150 µm, except for one variety with 15 µm. The number of trichomes varied from 0 to moderate values (40 tpi). Thus, despite sufficiently wide variations, the indicators did not show high values for the length and quantity of trichomes (17).

Large quantities and longer sizes of trichomes lead to a decrease in transpiration processes in the epidermal layer of leaves. Leaf stomata and their closure get well developed in drought-resistant wheat varieties as an adaptation mechanism to water deficits. With increases in the degree of drought, in stress-resistant varieties, the amount of trichomes increases as an ecological adaptation (4). There are ideas that the drought resistance of wheat varieties is influenced by many factors (9). The amount and size of mesophyll cells, as well as the amount and size of stomata in the leaf epidermis, cause changes in the anatomical structure of wheat plant leaves under drought conditions (5).

The drought resistance of the varieties is determined by the small size of the leaf area and the small number of leaf stomata. Besides, a correlation was observed between the thickness of the cuticle layer of leaves and the rate of water loss in the dark in the drought-resistant varieties. Based on microscopic analysis, damage to the cell membrane was detected due to the leakage of electrolytes from the cells of susceptible varieties compared to resistant varieties. It was observed that cell membrane integrity and water holding capacity were maintained in susceptible varieties subjected to repeated stress (13). Because of continuous drought stress, the epicuticula layer was not damaged in resistant varieties. Disruption of chloroplast structure, leakage of electrolytes, and a decrease in leaf RWC were observed (13).

CONCLUSION

During the phenol typing of trichomes of wheat genotypes, it was noted that although the formation of the number and length of trichomes depend on the level of climate humidity, the individuality of genotypes is more dependent on the development of trichomes. Trichomes, which are better developed under conditions of abiotic stress, increase the resistance of genotypes to conditions of biotic stress.

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