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The influence of conditions on water holding capacity characteristics of triticale varieties planted in the Samarkand region

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Abstract

In this article, the possibilities of water holding capacity in the leaves of triticale varieties were studied in the conditions of LFMC-70% and arid LFMC -50% of grassland-gray soils of Samarkand region, and the drought resistance characteristics of the varieties were studied. LFMC (Limited Field Moisture Capacity) was maintained at 70% under normal conditions and LFMC at 50% under dry conditions. According to the results of the experimental analysis, drought conditions had a significant and negative effect on the productivity of all studied genotypes. It was found that triticale cultivars "Odessiy" and "Tikhon" grown under LFMC-50% conditions in drought conditions meet water deficit less in all development phases and at all times of the day and are drought resistant compared to other cultivars. Analysis of the physiological and biochemical bases of adaptation in the selection of drought-resistant triticale varieties and the research conducted on the selection and obtaining of fertile varieties suitable for this region are described.

Keywords

drought; grain; productivity; physiological; Samarkand; triticale; water

Introduction

Drought is a major abiotic constraint on crop productivity and is expected to become more severe due to climate change. Drought has a significant impact on food security, especially in areas where crop production depends solely on rainfall. In arid and semi-arid regions with very little rainfall, water scarcity (drought) is a major problem. As a result of climate change and variability, many of these areas are expected to experience less rainfall and become drier. Global warming is also expected to reduce soil moisture through increased evaporation, thereby inhibiting plant growth (1). In recent decades, the intensification of agricultural systems in response to global food demand has increased the ecological footprint of food production, directly affecting freshwater and landscape degradation (2). Agriculture consumes about 70% of global freshwater resources (FAO, 2010), and it is a major source of freshwater degradation due to nitrate leaching losses (3).

Changes in external factors lead to changes in the water content of most plants. In conditions of water scarcity, the amount of water in plant leaves and tissues decreases sharply (4). A decrease in the amount of water in tissues causes a slowdown in the main physiological and biochemical processes in the body of plants, resulting in a slowdown in the growth and development of plants (5).

Water scarcity is a major limiting factor in crop production worldwide. Knowledge of the genetics and physiology of tolerance mechanisms is necessary to develop a meaningful breeding program to improve plant drought tolerance. Productivity is the main selection index used under drought conditions (6). This requires the implementation of other productive grain crops that are resistant to diseases and pests. One such grain crop is triticale.

Today, the main producers of triticale are Poland, Germany, France, China, Australia, Hungary, the Czech Republic, and the USA. According to FAO data, in 2005, triticale was planted on 35.2 million ha, and 13.5 million tons of grains were grown worldwide. The largest producer is Poland (3.7 million tons), followed by Germany (2.7 million tons), France (1.8 million tons), China (1.25 million tons), and Hungary (0.57 million tons) (7).

Triticale is a type of crop resulting from the hybridization of wheat (Triticum) and rye (Secale) plants by breeders. In just over a century, triticale has evolved from a biological curiosity to a practical crop. Breeders have worked to overcome the main problems of triticale. Today, it is used as fodder or grain. The chemical composition of triticale is similar to that of wheat and rye and shows intermediate values in many parameters. Due to the presence of rye proteins, triticale flour has a low gluten content and low gluten viscosity and therefore produces lower quality bread than wheat. However, triticale is still an alternative for human food, mainly in areas where soil and climate conditions limit wheat growth (8). Many farmers replace wheat with triticale (× Triticosecale) because of its high yield and regional demand for animal feed as fodder and grain. In agrotechnical literature, triticale is characterized by higher abiotic stress tolerance compared to wheat (9).

Triticale combines the characteristics of the genome of wheat and rye, such as resistance to diseases, and the environment, because of the high yield potential and good quality of the grain. Therefore, it is particularly suitable for high acidity "substandard" soils, water scarcity, and high altitude or disease pressure environments (10). Triticale is known to have low production costs compared to other crops, low sensitivity to biotic stresses, thus reducing chemical protection and fertilization requirements, and high grain and large yields even in remote environments inaccessible to food crops, leading to biomass production (11).

Triticale is a crop resistant to stress factors, diseases, and high temperatures, and it is a crop that adapts quickly to unfavorable soil and climate (12). The high drought resistance of triticale can be attributed to its early heading date and the high capacity of its roots to absorb water from the soil (13). During grain ripening, triticale grains are resistant to drought and high temperatures. This is helped by the wax coating on the shoots, the developed root system, and the high water retention capacity of the variety. Therefore, it is recommended to plant in areas considered unfavorable for most crops due to abiotic stresses (14). Triticale is mainly used in agriculture as fodder, flour products, and green fodder. Triticale grain is recommended to replace 50% of conventional feeds in livestock and poultry diets (15).

The high amount of carotenoid and sugar content of triticale green mass makes it a nutritious feed for livestock. In several countries, including Spain, Hungary, Poland, Canada, and the USA, triticale is grown as a pasture plant (16). Western Canada aims to grow enough triticale to create a world-class biorefinery that will produce triticale-based energy, chemicals, biomaterials, and biocomposites (17).

Triticale flour is widely used in confectionery, but its baking properties are not good. That is why wheat and other grain plants are actively used in mixing with flour. As a result of such a mixture, triticale-wheat bread, which is closed without yeast, has a large size, excellent taste, and smell (18). Triticale protein has the property of forming a suitable film for antimicrobial food packaging (19).

Breeding of high-yielding and sustainable plant varieties under water-scarce drought conditions are essential. During the period of adaptation to soil drought, plants initiate defense mechanisms against water shortages (20). Drought affects the morphological, productivity, physiological, and biochemical processes of plants. Morphological indicators such as height of the plant, number of productive stems, biomass, and weight of 1000 grains are important for evaluating the resistance of cultural plants to drought. Plant height, as well as the number of leaves and fertile crops per plant, are significantly affected by environmental conditions and negatively affected by drought stress (21). The results of our study can serve as a theoretical basis for the cultivation of drought-tolerant triticale cultivars in normal and arid regions.

From the above, we can conclude that an in-depth study of triticale by our scientists, not only for food but also for the creation of competitive varieties resistant to various stress factors, according to the main economic benefits, is one of the urgent problems of today. This means a more active introduction of this crop into the agricultural production of our republic. This study aimed to evaluate the effect of drought stress on the physiological characteristics of triticale cultivars and identify drought-tolerant cultivars.

Materials and Methods

Experimental site and materials

Scientific research work was carried out in the meadow-gray soil conditions of Payariq district, Samarkand region (Fig. 1). The climate of the region is characterized by continental, strong solar radiation, daily and seasonal changes, long hot and dry summer seasons, and slightly cold winters (22). The average annual temperature is 13.4°C, the average temperature in January is 1.2°C, and the average temperature in July is 27°C. The highest temperature is

Fig. 1. Scientific research conducted on triticale varieties in the conditions of meadow-gray soil.

45°C, the lowest temperature is -28°C. The vegetation period suitable for plants is 190–200 days. The average annual precipitation is 312 mm, mainly in winter and spring. However, during these periods, the climatic conditions of each month differ from each other (23). Nowadays, the temperature in such regions is relatively high, as a result of which drought threatens the growth and development of plants. The cultivation of drought- and heat-resistant plants such as triticale in such regions is of great economic necessity, because triticale makes good use of autumn, winter, and spring rainfall in the area (24). Triticale (× Triticosecale) varieties with 5 genotypes: "Odessiy", "Tikhon", "Swat", "Valentin", and "Farkhod" were used. The variety "Farkhod" was selected as a control based on previous studies.

Determination of water retention and transpiration rates

Research was carried out in the form of laboratory and field experiments. Our research was conducted in 2 different conditions. Conditions with uniform humidity were kept at LFMC (limited field moisture capacity)-70%, and in dry conditions LFMC-50%. During the research, the properties of water retention in the leaves of triticale cultivars were studied in the phases of development in wet and dry conditions. The initial weight of the leaf samples taken for determination was measured on an analytical scale and kept at field temperature for 2 hrs (25). After 2 hrs, the withered leaf was found to be stolen again. The wilted leaf was dried for 3 hrs at 105°C (according to the method of L.G. Tretyakov, A.S. Sulaymanov) by drying the amount of dry matter in a drying cabinet to a constant mass, and its value was determined (25). The water retention capacity of triticale varieties is determined by the following equation:

$$x = \frac{b * 100}{A}$$

…………………(Eqn. 1)

Here, X - is the ability of leaves to retain water, in %, A - is the amount of water in the original leaf, in g. b - is the amount of water lost by the leaves during 2 hrs of wilting.

In the course of the research, the transpiration rate of triticale cultivars was studied in the development phases in dry and humid conditions. The rate of transpiration was determined on a KERN ABJ-NM/ABS-N analytical electronic balance. Leaf level was determined by the Lazerov method. The transpiration rate of triticale varieties is determined by the following equation:

$$U = \frac{a * 10000 \ sm^2}{b}$$

……………(Eqn. 2)

Here, U - transpiration rate, g/m^2/s, a - amount of water evaporated for 10 min. in g, b - leaf area, in cm^2, 10000 cm^2 is the conversion factor to m^2.

Statistical analysis

The statistical processing of the results collected during scientific research was carried out based on the recommendations of B. A. Dospekhov (26). SAS software was used to analyze the variance of the data. A protected LSD test ($p<0.05$) was also used for mean comparisons. All drought resistance indices were calculated using Excel 2010 software. Using SAS software, simple Pearson correlation analysis was performed to calculate the correlation between the investigated plant characteristics and the estimated drought tolerance indices.

Results and Discussion

In our research work, we studied the amount of water in the leaves of triticale cultivars in conditions of LFMC-70%, and in dry conditions-LFMC (50%). The obtained results are presented (Table 1). It was observed that the amount of water in the leaves decreases from the morning until 2 p.m., and then the amount of water increases again until the evening. This pattern was observed in all varieties and phases. It was determined that the time of the lowest water level was at 14 p.m. In the conditions of LFMC-70%, high water retention properties in all phases were observed in the "Valentin" and "Odessiy" varieties, while relatively lower water holding capacity properties were observed in the "Farkhod" and "Tikhon" varieties. It was observed that the amount of water in the leaves of triticale varieties decreased slightly from the tuberization phase to the flowering phase, compared to the flowering phase, high water-holding capacity properties can be seen in the "Valentin" and "Odessiy" varieties in these phases as well.

When analyzing the water retention capacity of triticale varieties grown in dry conditions and in water-sufficient conditions, it was observed that plants growing in dry conditions have a slightly higher water retention capacity. The drought tolerance of triticale cultivars under water-limited conditions may be related to their lower flag leaf angle, lower leaf area, and lower number of stomata (6).

Table 1. Leafs water holding capacity of triticale varieties under dry and humid conditions 2022–2023 (in % of full saturation).

No.	Varieties	Phases of development	LFMC-70%			LFMC-50%		
			Daily average (%)		Daily variation range	Daily average (%)		Daily variation range
			Water loss	Water storage		Water loss	Water storage	
1	Farkhod	Tillering	14.1±0.4	85.9±0.6	5.8	12.5±0.3	87.5±0.6	5.1
2	Odessiy		10.3±0.3	89.7±0.5	7.0	11.5±0.4	88.5±0.5	5.4
3	Valentin		12.4±0.5	87.6±0.3	5.1	13.2±0.5	86.8±0.7	6.0
4	Swat		13.2±0.3	86.8±0.8	6.8	12.8±0.3	87.2±0.9	5.4
5	Tikhon		13.8±0.2	86.2±0.7	7.7	12.0±0.5	88.0±0.8	6.2
1	Farkhod	Heading	17.1±0.5	82.9±0.9	8.6	16.9±0.4	83.1±0.8	6.8
2	Odessiy		13.8±0.6	86.2±0.6	7.4	12.2±0.3	87.8±0.7	4.6
3	Valentin		14.7±0.4	85.3±0.5	8.2	16.6±0.5	83.4±0.9	7.5
4	Swat		15.8±0.6	84.2±0.7	8.3	15.7±0.8	84.3±1.0	6.0
5	Tikhon		17.0±0.7	83.0±0.4	8.4	14.9±0.7	85.1±0.9	6.1
1	Farkhod	Spike	19.7±0.5	80.3±0.9	7.6	17.6±0.6	82.4±0.8	6.3
2	Odessiy		15.8±0.4	84.2±0.7	8.2	14.7±0.5	85.3±1.1	5.2
3	Valentin		16.4±0.6	83.6±0.8	8.3	18.5±0.7	81.5±0.9	6.8
4	Swat		17.2±0.8	82.8±0.9	7.9	16.5±0.8	83.5±0.7	7.7
5	Tikhon		18.7±0.3	81.3±0.8	8.8	15.5±0.6	84.5±0.8	5.7
1	Farkhod	Bloom	21.1±0.4	78.9±1.2	8.1	18.1±0.7	81.9±1.3	6.9
2	Odessiy		18,7±0.5	81.3±0.7	7.2	16.7±0.6	83.3±0.8	5.8
3	Valentin		17.6±0.6	82.4±0.8	8.7	19.1±0.8	80.9±0.7	7.5
4	Swat		19.4±0.5	80.6±1.1	9.1	17.2±0.7	82.8±0.9	8.4
5	Tikhon		20.2±0.8	79.8±1.0	9.5	16.9±0.5	83.1±1.3	6.7
1	Farkhod	Grain ripening	20.1±0.8	79.9±0.9	8.5	19.3±0.8	80.7±1.2	6.6
2	Odessiy		18.8±0.7	81.2±0.8	8.1	16.2±0.7	83.8±1.4	5.5
3	Valentin		17.1±0.6	82.9±0.7	8.8	19.5±0.9	81.5±0.9	7.4
4	Swat		19.8±0.6	80.2±0.8	9.0	18.6±0.8	81.4±1.0	8.3
5	Tikhon		21.9±0.7	78.1±1.2	9.5	17.2±0.6	82.8±0.9	7.1

In dry conditions, "Valentin" and "Farkhod" cultivars had relatively lower water holding capacity in their leaves. In the "Tikhon" and "Odessiy" varieties, it was observed that the ability to store water in the leaves is relatively high in dry conditions. High water retention properties were observed in the "Odessiy" and "Tikhon" varieties during the accumulation phase, the daily medium water content was 88.5% in the "Odessiy" variety and 88% in the "Tikhon" variety, the daily variation range was 5.4% in the "Odessiy" variety, and it was found to be 6.2% in the "Tikhon" variety. A lower indicator of water retention was observed in the "Valentin" variety.

"Odessiy" and "Tikhon" cultivars showed high water retention during the hearing, flowering, and grain ripening phases. It was found that the "Odessiy" and "Tikhon" varieties of triticale grown in arid conditions face less water deficit in all development phases and at all times of the day and are resistant to drought compared to other varieties. Lack of water is the most damaging effect on the plant. One of the global problems in the current era, drought, has had the highest impact. The need for such drought-tolerant crops is increasing. Triticale can withstand water shortages, and it is important to distinguish between biological and agronomic droughts (27). The selection and use of varieties resistant to the effects of drought are of great importance (28). Such varieties are distinguished by a high synthetic ability of enzymes, high amount of bound water, high concentration of cell sap, strong pigment system, strong ability to store water, and high ability to accumulate organic matter. Relative water content is mentioned as a suitable indicator of the water status of leaves, which decreases under water deficit stress, causes changes in the cell membrane, and increases the leakage of electrolytes from the cells (29).

The moisture limit at which plants stop using soil water is the wilting point. The efficiency of the use of consumed moisture is evaluated by the transpiration coefficient. The transpiration coefficient largely depends on the soil moisture during the growing season of plants and the characteristics of the cultivated crop (30). The rate of transpiration of plants varies depending on their geographical location, soil-climate conditions, and plant type. The accumulation of vegetative mass in triticale occurs most intensively from the stage of tuberization to flowering. During this period, plants require moisture the most (31). But in this area, there is a certain amount of natural precipitation during that period, and the triticale plant takes advantage of this and gives a certain amount of biomass. By studying the transpiration rate of triticale, we conducted these studies in order to differentiate the drought tolerance of the varieties. In our research work, the transpiration rate of triticale varieties was studied in water-sufficient conditions (LFMC-70%), and in dry conditions (LFMC-50%). The obtained results are presented (Table 2). In the accumulation phase, a low rate of transpiration was observed in the morning hrs, from 40.6 g/m^2 h to 63.4 g/m^2 h.

During the flag leaf formation phase, the transpiration process is accelerated. In this phase, it was found that the time of rapid transpiration is from 148.3 g/m^2 h to 183.7 g/m^2 h at 14 pm. It was observed that the low rate of transpiration in the tuber phase was from 62.4 g/m^2 h to 95.6 g/m^2 h in the morning hrs. According to the data presented in Table 2, it was found that the most transpiration in triticale varieties occurs during the flowering phase. During the flowering phase of the triticale variety, it was observed that the most rapid transpiration occurred at 14 pm. According to this, the rate of transpiration was determined to be from 320.6 g/m^{2}h to 379.5 g/m^{2}h. Relatively slow transpiration in the flowering phase was observed in the morning hrs, ranging from 108.5 g/m^2 h to 135.8 g/m^2 h. Among triticale varieties, the highest rate of transpiration was observed in the "Tikhon" variety.

In the grain ripening phase, the transpiration rate slightly decreased compared to the flowering phase, and it was observed that the transpiration rate at 14:00 was 225.3 -288.6 g/m^2. At this stage, transpiration was determined in the morning hours, which was 93.3-119.6 g/m^2. According to our research, the transpiration level of "Odessiy" and "Valentin" triticale varieties is slightly lower in all phases and at all times of the day when there is enough moisture. It was found that transpiration is slightly faster in the "Tikhon" variety. The reason for this was that the vegetation of the "Tikhon" variety lasted longer than the other varieties and went into phases later. The obtained results are presented (Table 3).

In arid conditions (LFMC-50%), it was observed that the rate of transpiration decreased significantly in all development phases of triticale varieties. Due to the low temperature during the accumulation phase, there was no significant difference between normal and dry conditions.

It was found that the time of rapid transpiration in the tuber phase was from 138.6 g/m^2 h to 170.4 g/m^2 h at 2 pm. It was also observed that the low rate of transpiration in the tuber phase was from 53.3 g/m^2 h to 80.6 g/m^2 h in the morning hrs. In dry conditions, compared to normal conditions, the rate of transpiration was 9.1–15.0 g/m^2 h in the morning and 9.7–13.3 g/m^2 h at 2 pm.

During the peak phase, we observed rapid transpiration from 250.4 g/m^2 h to 267.1 g/m^2 h at 2 pm., and relatively slow transpiration from 85.3 g/m^2 h to 99.7 g/m^2 h in the morning. In dry conditions, the rate of transpiration was 14.2–15.6 g/m^2 h in the morning and 25.4–38.0 g/m^2 h in the afternoon. In dry conditions, the rate of transpiration was 16.7 g/m^2/h lower in the "Odessiy" variety compared to normal conditions, while it was significantly lower in the "Tikhon" variety by 45.7 g/m^2 h. It was found that the highest transpiration rate in the development phases of triticale varieties corresponds to the flowering phase. It was observed that the time of the most rapid transpiration is at 2 pm in this phase as well. Accordingly, it was observed that the rate of transpiration was from 269.5 g/m^{2}h to 300.9 g/m^2 h and from 93.5 g/m^2 h to 105.0 g/m^{2}h in the morning hrs. In dry conditions, compared to normal conditions, the rate of transpiration was 15.0–30.8 g/m^2 h in the morning and 51.1–78.6 g/m^2 h at 2 pm.

In the grain ripening phase, the rate of transpiration slightly decreased compared to the flowering phase, and

Table 2. Transpiration rate of triticale varieties (LFMC-70%), g/m²/h.

LFMC-70%										
No.	Varieties	Phases of development	Determination periods							Daily average
			6^{00}	8^{00}	10^{00}	12^{00}	14^{00}	16^{00}	18^{00}	
1	Farkhod	Tillering	52.4±0.9	58.5±0.8	66.3±0.8	73.5±0.9	75.0±0.7	65.3±0.8	57.4±0.7	64.1
2	Odessiy		40.6±0.8	54.3±0.9	57.2±0.8	60.3±0.8	63.6±0.8	56.0±0.7	51.2±0.5	54.7
3	Valentin		49.8±0.9	56.0±0.7	60.2±0.7	61.4±0.8	69.7±0.7	54.7±0.6	49.4±0.6	57.3
4	Swat		52.4±1.1	58.0±0.8	63.1±0.9	70.0±0.9	72.1±0.9	59.7±0.7	49.2±0.6	60.6
5	Tikhon		63.4±1.0	64.0±0.9	69.8±0.8	74.6±0.7	77.3±0.6	60.0±0.8	62.8±0.8	67.4
1	Farkhod	Heading	78.8±1.3	121.0±1.0	142.5±1.3	153.2±1.3	183.7±1.2	148.2±1.2	108.5±1.1	133.7
2	Odessiy		68.5±1.2	118.7±1.1	139.3±1.2	145.2±1.5	148.3±1.1	135.2±1.3	103.6±1.2	122.7
3	Valentin		62.4±1.1	123.1±1.2	136.8±1.1	155.5±1.6	161.0±1.2	147.9±1.1	91.6±1.0	125.5
4	Swat		75.5±1.2	140.6±1.3	165.5±1.8	170.1±1.5	176.2±1.3	144.7±1.5	103.6±1.1	139.5
5	Tikhon		95.6±1.3	145.0±1.5	157.7±1.7	160.7±1.7	172.2±1.4	152.0±1.6	102.3±1.2	140.8
1	Farkhod	Spike	111.7±1.5	134.5±1.3	200.9±2.1	237.3±2.1	283.6±1.9	225.6±1.9	120.7±1.5	187.8
2	Odessiy		99.5±1.1	124.8±1.2	162.6±2.1	205.8±2.3	278.5±1.8	199.8±1.8	111.7±1.4	169.0
3	Valentin		103.8±1.3	131.5±1.1	174.1±1.9	223.5±2.5	275.8±1.8	215.6±1.9	120.6±14	177.8
4	Swat		115.3±1.2	139.3±1.4	202.6±2.2	258.8±2.4	305.1±2.4	236.3±2.1	118.2±1.6	196.5
5	Tikhon		102.9±0.9	124.4±1.3	218.1±2.3	281.9±2.1	301.0±2.1	250.8±2.2	129.9±1.7	201.3
1	Farkhod	Bloom	121.8±1.2	185.9±1.7	232.9±2.4	315.8±2.9	340.3±2.2	252.7±2.1	186.5±1.9	233.7
2	Odessiy		108.5±1,1	189.6±1.6	217.5±2.1	278.0±2.8	320.6±2.4	222.6±2.2	165.8±1.7	214.7
3	Valentin		114.6±1.3	174.9±1.5	228.6±2.2	288.9±2.7	332.5±2.3	233.6±2.4	178.2±1.7	221.6
4	Swat		135.8±1.6	241.2±2.1	272.4±2.6	320.5±2.6	359.0±2.5	224.6±2.5	142.1±1.5	242.2
5	Tikhon		126.2±1.8	194.1±1.8	266.5±2.7	331.7±2.5	379.5±2.5	287.0±2.5	180.9±1.8	252.3
1	Farkhod	Grain ripening	93.3±1.1	131.7±1.6	179.1±1.9	223±2.1	238.8±2.3	215.6±2.1	132.7±1.6	173.5
2	Odessiy		101±0.9	143.3±1.5	157.6±1.7	189.2±1.9	225.3±2.1	195.6±1.9	115.8±1.2	161.1
3	Valentin		96.3±1.3	140.2±1.7	169.9±1.5	196.4±1.8	230.3±2.2	203.5±1.9	119.4±1.2	165.1
4	Swat		109.6±1.1	140.5±1.5	170.3±1.8	203.5±2.1	250.9±2.1	210.0±2.1	119.7±1.1	172.1
5	Tikhon		119.6±1.2	139.1±1.4	194.7±1.7	247.9±2.2	288.6±1.9	236.1±2.2	159.9±1.7	198.0

at this time, it was observed that the rate of transpiration was at 2 pm (175.6–219.2 g/m² h). In this phase, transpiration was found to be in the morning hrs (60.3–79.4 g/m² h). In dry conditions, the rate of transpiration was 33.3 – 40.2 g/m² h in the morning and 49.7–69.4 g/m² h at 2 pm. The increase in temperature and decrease in air humidity affected the rate of transpiration in dry conditions. As a result, a decrease in the rate of transpiration was observed in plants growing in arid conditions, even with efficient use of water.

In dry conditions (LFMC-50%), it was found that the transpiration rate was slightly lower in the triticale varieties "Odessiy" and "Tikhon" in all phases and at all times of the day. It was found that transpiration is slightly faster in the "Valentin" variety in the flowering and tuberting phases, in the "Svat" variety in the earing phase, and in the "Farkhod" variety during flowering and grain ripening.

In our research, we also paid attention to the study of the effect of conditions on the productive indicators of triticale, and the obtained results are presented in Table 4. When analyzed according to morphological indicators in the experiment, the average stem height of triticale varieties under LFMC-70% conditions were 100.6 to 130.9 cm and when analyzed under dry conditions, the average stem height was 96.9 to 118.8 cm. Stem height does not always determine yield. In dry conditions, "Tikhon" was lower compared to the rest of the variety, but the yield indicators were high. This indicates that the "Tikhon" variety of triticale is resistant to drought conditions.

It was found that the length of the last joint in triticale varieties is in the range of 29.7–41.5 cm under water-sufficient conditions (LFMC-70%), the lowest joint length is 29.7 cm in the "Swat" variety, and the highest result was noted to be 41.5 cm in the "Odessiy" variety. In the dry conditions (LFMC-50%), it was found that the length of the last joint in triticale varieties was in the range of 26.1–38.1 cm and the lowest joint length was 26.1 cm in the "Swat" variety and the highest result was 38.1 cm in the "Farkhod" variety.

When the spike length was analyzed in triticale varieties, a long spike (13.7 cm) was observed in the "Odessiy" variety and shortest spike was observed in the "Tikhon"

Table 3. Transpiration rate of triticale varieties (LFMC-50%), g/m²/h.

No.	Varieties	Phases of development	Dry conditions (LFMC-50%) Determination periods 6^{00}	8^{00}	10^{00}	12^{00}	14^{00}	16^{00}	18^{00}	Daily average
1	Farkhod	Tillering	50.2±0.7	54.6±0.8	66.3±0.9	63.2±0.7	74.6±0.8	68.6±0.6	55.3±0.7	50.2
2	Odessiy		44.8±0.6	49.2±0.7	62.6±0.8	54.1±0.8	59.7±0.5	54.6±0.8	53.3±0.5	44.8
3	Valentin		54.9±0.8	60.9±0.9	62.6±0.8	67.8±0.8	70.1±0.6	54.3±0.5	58.2±0.6	54.9
4	Swat		50.4±0.8	49.4±0.8	71.6±0.7	61.6±0.7	69.7±0.7	56.0±0.6	51.2±0.5	50.4
5	Tikhon		48.6±0.7	58±0.9	60.2±0.6	63.5±0.7	68.7±0.6	59.7±0.7	49.2±0.6	48.6
1	Farkhod	Heading	58.9±0.9	118.4±1.1	123.5±1.7	141.4±1.2	170.4±1.5	136.6±1.5	105.7±1.3	122.1
2	Odessiy		53.3±0.8	106.6±1.2	102.6±1.2	133.7±1.3	138.6±1.4	135.3±1.2	96.81±1.1	109.6
3	Valentin		60.5±0.9	120.6±1.3	130.5±1.3	148.3±1.1	159.6±1.5	144.4±1.1	100.8±1.4	123.5
4	Swat		55.3±0.7	126.6±1.2	126.2±1.4	139.9±1.3	160.9±1.7	139.9±1.3	101.9±1.3	121.5
5	Tikhon		80.6±0.9	115.8±1.1	127.6±1.3	132.2±1.2	139.2±1.6	131.3±1.2	109.6±1.1	119.5
1	Farkhod	Spike	99.7±0.9	111.6±1.4	174.1±1.6	220.9±1.8	262.4±2.1	197.7±1.6	94.8±0.9	165.9
2	Odessiy		85.3±0.8	99.5±0.9	165.0±1.5	205.9±1.8	250.4±2.3	170.6±1.7	89.3±0.9	152.3
3	Valentin		93.3±0.8	120.8±1.1	168.0±1.5	220.0±1.7	262.5±2.5	181.1±1.7	96.2±1.1	163.1
4	Swat		87.2±0.7	131.8±1.3	194.0±1.9	225.8±1.9	267.1±2.4	203.5±1.9	92.4±0.8	171.7
5	Tikhon		91.7±0.6	106.6±1.2	166.8±1.7	213.2±2.1	252.5±2.4	175.6±1.8	82.9±0.9	155.6
1	Farkhod	Bloom	104.7±1.2	165.8±1.5	193.2±1.8	275.5±2.3	298.5±2.1	227.1±2.1	133.3±1.2	199.7
2	Odessiy		98.3±1.1	159.0±1.6	197.6±1.9	237.9±2.2	277.5±2.6	207.8±1.9	95.5±0.9	181.9
3	Valentin		105.0±1.3	162.8±1.7	214.6±2.1	244.2±2.3	284.3±2.7	209.0±1.8	135.2±1.3	193.6
4	Swat		99.1±0.9	164.2±1.5	189.5±1.9	255.9±2.1	300.9±2.8	204.7±1.7	97.3±1.1	187.4
5	Tikhon		93.5±0.8	159.9±1.4	204.7±2.3	2[illegible]0.3±2.4	269.5±2.6	193.2±1.9	107.5±1.6	18[illegible].5
1	Farkhod	Grain ripening	60.3±0.9	94.8±1.1	173.7±1.8	205.9±2.1	219.2±2.7	209.5±1.8	109.7±1.2	153.3
2	Odessiy		67.2±0.8	105.4±1.2	146.0±1.8	192.0±1.9	175.6±1.9	155.0±1.7	88.4±0.8	132.8
3	Valentin		74.2±0.7	105.6±1.2	151.4±1.7	182.5±1.6	194.5±1.8	181.7±1.5	99.5±0.9	141.3
4	Swat		79.4±0.7	111.4±1.3	158.2±1.5	179.1±1.8	191.0±1.5	178.1±1.6	105.0±0.9	140.3
5	Tikhon		76.5±0.8	94.3±0.9	160.1±1.5	165.8±1.7	188.5±1.7	150.8±1.5	92.1±0.7	132.6

Table 4. Productivity indicators of triticale varieties for 2022–2023.

No.	Varieties	1 m² - the number of productive stems	Height (cm)	Last syllable length (cm)	Spike length (cm)	The number of spikes in a kernal	The number of grains in the seed	Grain mass in 1 seed (g)	Mass of 1000 grains (g)
	LFMC-70%								
1	Farkhod	345±2.3	130.1±2.9	41.2±1.1	13.5±0.9	26.8±1.1	52.0±2.1	2.3±0.6	45.2±2.1
2	Odessiy	403±3.8	121.0±2.5	41.5±1.3	13.7±0.7	27.1±1.4	58.2±2.3	2.6±0.5	46.2±1.9
3	Valentin	370±2.9	130.9±3.1	37.5±0.9	13.2±0.8	31.3±1.3	55.4±1.9	2.4±0.8	43.1±2.3
4	Swat	359±3.1	115.7±2.3	29.7±0.8	13.6±0.8	29.4±1.1	50.0±2.1	2.3±0.6	47.6±2.1
5	Tikhon	361±2.5	100.6±1.9	30.2±1.2	12.3±0.6	26.5±1.2	46.3±1.8	2.3±0.7	50.1±2.4
	LFMC-50%								
1	Farkhod	325±2.1	118,8±2.5	38,1±1.4	13.3±0.7	24.7±0.9	50.1±2.1	2.1±0.8	43.2±2.4
2	Odessiy	361±2.3	112,3±2.1	36,4±1.2	13.0±0.8	26.4±1.1	53.1±2.3	2.3±0.9	44.1±2.6
3	Valentin	323±2.2	118,5±2.4	34,2±1.1	13.5±0.7	28.0±1.3	50.6±2.2	2.1±0.7	41.7±2.1
4	Swat	340±2.3	111,4±2.1	26,1±0.8	12.7±0.9	27.6±1.2	48.3±2.1	2.2±0.9	45.3±1.9
5	Tikhon	353±1.9	96,9±2.3	27,3±1.1	11.1±0.8	25.8±1.1	48.0±2.3	2.3±0.8	47.3±2.2

variety (12.3 cm) under sufficient water conditions. In dry conditions, the longest spike was observed in the "Valentin" variety (13.5 cm), and the shortest spike was observed in the "Tikhon" variety (11.1 cm). It was found that the spike length of the variety "Tikhon" is shorter than the rest of the varieties, even under sufficient moisture and dry conditions.

The highest result in terms of the number of grains per spike was observed in the "Odesiy" variety under the conditions of LFMC-70%, 58.2 pieces, while the lowest value was recorded in the "Tikhon" variety, 48.0 pieces. In the dry conditions, 53.1 units were observed in the "Odessiy" variety, while the lowest indicator was 48.3 units in the "Svat" variety.

When analyzing the conducted experiments, a high result in terms of grain weight per spike was observed in the "Odessiy" variety even under conditions of LFMC-70% and LFMC-50%. In the conducted experiments, the highest result by weight of 1000 grains was determined in the "Tikhon" variety even with enough water and in dry conditions, while the lowest result was observed in the "Valentin" variety. In dry conditions, the productivity indicators of triticale varieties are slightly reduced compared to conditions with sufficient moisture. The reason for this is the slowing down of physiological processes, especially during the flowering phase, due to the lack of water for pollination and grain formation. Abiotic stresses reduce plant height and yields. Root dry weight increased with drought stress and decreased when salinity and drought were applied simultaneously (29). Some of the known advantages of triticale include performance in marginal soils, disease resistance, low fertilizer use, and high yield of high-quality straw (32). At the end of our research, we studied the effect of conditions on productivity, and the obtained results are presented in Fig. 2.

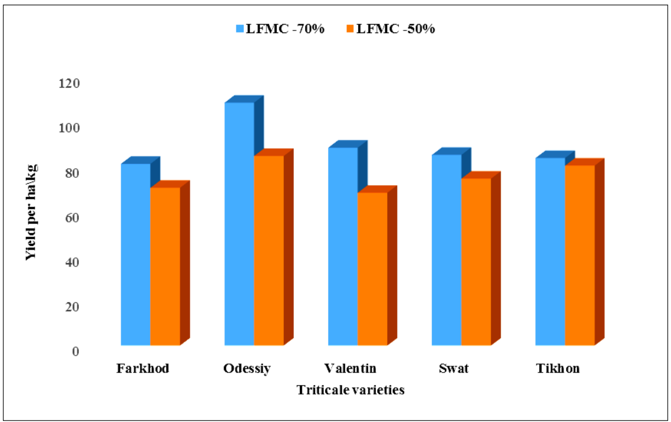

Fig. 2. Triticale yield under LFMC-70% and 50% conditions.

Under the conditions of LFMC-70%, the average grain yield of triticale varieties is 81.1-108.4 s/ha, the highest grain yield is in "Odessiy" variety (108.4 s/ha), and the lowest grain yield is in "Farkhod" variety (81.1 s/ha) was observed. Under dry LFMC-50% conditions, the average grain yield of triticale varieties is 68.2-84.6 s/ha, the highest grain yield is in "Odessiy" variety (84.6 s/ha), and the lowest grain yield is in the "Valentin" variety (68.2 s/ha). "Odessiy" variety of triticale showed high results in both conditions.

Among triticale varieties, "Odessiy" and "Tikhon" varieties were the most resistant to drought, and "Valentin" was the most sensitive genotype to water stress. Under drought stress, leaf water retention showed a significant and negative relationship with grain yield, while their relationship was significant and positive under moisture-sufficient conditions. This relationship shows that the water storage properties of leaves have a significant effect on grain yield both under water-sufficient conditions and under drought conditions.

Conclusion

In this study, when analyzing the results of the characteristics of water exchange in leaves, productivity and grain yield under the conditions of sufficient moisture LFMC-70% and dry LFMC-50%, the lack of moisture to plants affected the grain yield. According to the results, it was found that the variety "Odessiy" is resistant to both environmental conditions. It was found that "Odessiy" and "Tikhon" varieties of triticale grown in arid conditions face less water deficit in all development phases and at all times of the day and are resistant to drought compared to other varieties.

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Authors' contributions

MU and SU contributed for data formal analysis, methodology, writing-original draft, writing-review and editing. XD and JZ analyzed and constructed methodology. KX and SV reviewed this manuscript.

Compliance with ethical standards

Conflict of interest: No conflict of interest was stated by the authors.

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