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DROUGHT TOLERANCE IN WINTER WHEAT CULTIVARS GROWN IN KAZAKHSTAN AND UZBEKISTAN

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SUMMARY

Drought is one of the consequences of climate change, negatively affecting crop yields. Current weather abnormalities showed that increasing plant resistance to temperature stresses needs special attention in Kazakhstan and Uzbekistan. The article provides information on weather and climatic condition variations in winter-growing regions of Kazakhstan and Uzbekistan. In 2021–2023, during the growing season, the increased air temperature in Kazakhstan (1.73 °C–2.60 °C) and Uzbekistan (1.97 °C–2.57 °C) materialized with decreased precipitation compared with the past average annual data. Recently, similar rainfall in these regions has been uneven during the winter crop-growing season. The current winter wheat (*Triticum aestivum* L.) cultivars and their study methods had reports of chief indicators of drought tolerance. The influence of flag leaf parameters (length, width, and area), leaf rolling during drought, slowing down of "Stay-green" plant aging, plant pubescence, and waxy patina on drought tolerance of winter wheat came about based on past research. Winter wheat cultivar evaluations for productivity indicators occurred under natural drought conditions. Characteristics of modern drought-tolerant winter wheat cultivars planted in Kazakhstan and Uzbekistan were informative.

Keywords: Winter wheat (*T. aestivum* L.), climate change, drought, drought-tolerant indicators, breeding for drought tolerance, productivity

Key findings: Climate change toward aridity requires a detailed study of drought-tolerant traits in winter wheat (*T. aestivum* L.) worldwide. In drought conditions of Kazakhstan and Uzbekistan, local varieties identified with high ear productivity and grain yield have been successful.

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INTRODUCTION

Drought is one of the life-threatening abiotic stress factors in the agriculture sector worldwide. The climatic phenomenon comprises the lack of water, a complex combination of temperature stress, less moisture, dry spells, and other factors. Concerning duration, drought can be short- and long-term, characterized by varying degrees of intensity (Passioura, 2007). Climate change can lead to higher temperatures in the future, which may reduce crop production in numerous crucial regions. Currently, in Kazakhstan and Uzbekistan, research quantifying the relationship between weather variables and wheat (*Triticum aestivum* L.) yields is rapidly expanding (Karatayev *et al.,* 2022; Baboeva *et al.,* 2023; Turaev *et al.,* 2023).

Wheat crops mainly receive adverse climate change effects. Therefore, a better knowledge and understanding of the agronomic relationship between weather conditions and wheat yields is decisive in predicting and responding to future temperature increases (Tacka *et al.,* 2015). Three drought types reveal distinction by the time of occurrence, i.e., spring, summer, and fall drought. Spring drought contains dry winds with relatively low air temperatures. Summer drought describes low relative humidity, high temperatures, and evapotranspiration. Autumn drought is characteristic of increased temperature, lack of rainfall, and soil drying to the depth of sowing winter wheat seeds. Climate change, including high temperatures, has declining effects on wheat productivity, and modeling studies predict more frequent heat waves in the future. Wheat growth disruption can also be due to high day and night temperatures at any stage of development, especially at the grain-filling stage (Pradhan *et al.,* 2020).

Climate change toward aridity

Nowadays, one of the most acute environmental problems is climate change toward aridity. Moreover, in grain crop-growing regions, the wet season often replaces the dry season, causing infectious diseases to develop. In this regard, large breeding centers (CIMMYT and ICARDA) are trying to breed wheat cultivars with drought tolerance and immunity to different diseases. Drought is an urgent problem for most parts of Central Asia. Moreover, according to well-known climatologists (Hunt *et al.,* 2021), the probability of this catastrophe will considerably enhance in the coming decades. The analysis of the meteorological data in Kazakhstan and Uzbekistan showed an increase in air temperature and a decrease in precipitation in recent years (Figure 1).

A significant increase in air temperature from March to July transpired in Kazakhstan and Uzbekistan during 2021–2023 (Figure 1). In these countries, the deviation of air temperature from the multiyear average for April, May, and June amounted to 2.17 °C and 2.47 °C, 1.73 °C and 1.97 °C, and 2.60 °C and 2.57 °C, respectively. It means that these regions are experiencing climate warming, ranging from 1.73 °C to 2.60 °C. According to the Global Climate Report (2023), the months (June to December) were the hottest on record, and global temperatures were more than 1.0 °C above the long-term average (Lindsey and Dahlman, 2024). However, the temperature increase in Kazakhstan (1.73 °C–2.60 °C) and Uzbekistan (1.97 °C–2.57 °C) can be extremely high.

Critically, in recent years, in these regions, the precipitation indicated a decreased ratio with unevenness during the growing season with increased air temperature. Thus, in the Almaty Region in March, the rainfall was, on average, 50.30 mm more, while in April and June (51.40 and 38.03 mm, respectively) was less than the past multiyear norms. In the Tashkent Region in April, May, and June, the average rainfall for 2021–2023 was significantly lower than the long-term data, and the difference amounted to 36.47, 19.40, and 9.80 mm, respectively.

Climate warming and improved cultivation technologies have led to changes in the structure of wheat fields. Today, Kazakhstan's South and Southeast farming communities have almost abandoned spring wheat growing and switched to winter wheat.

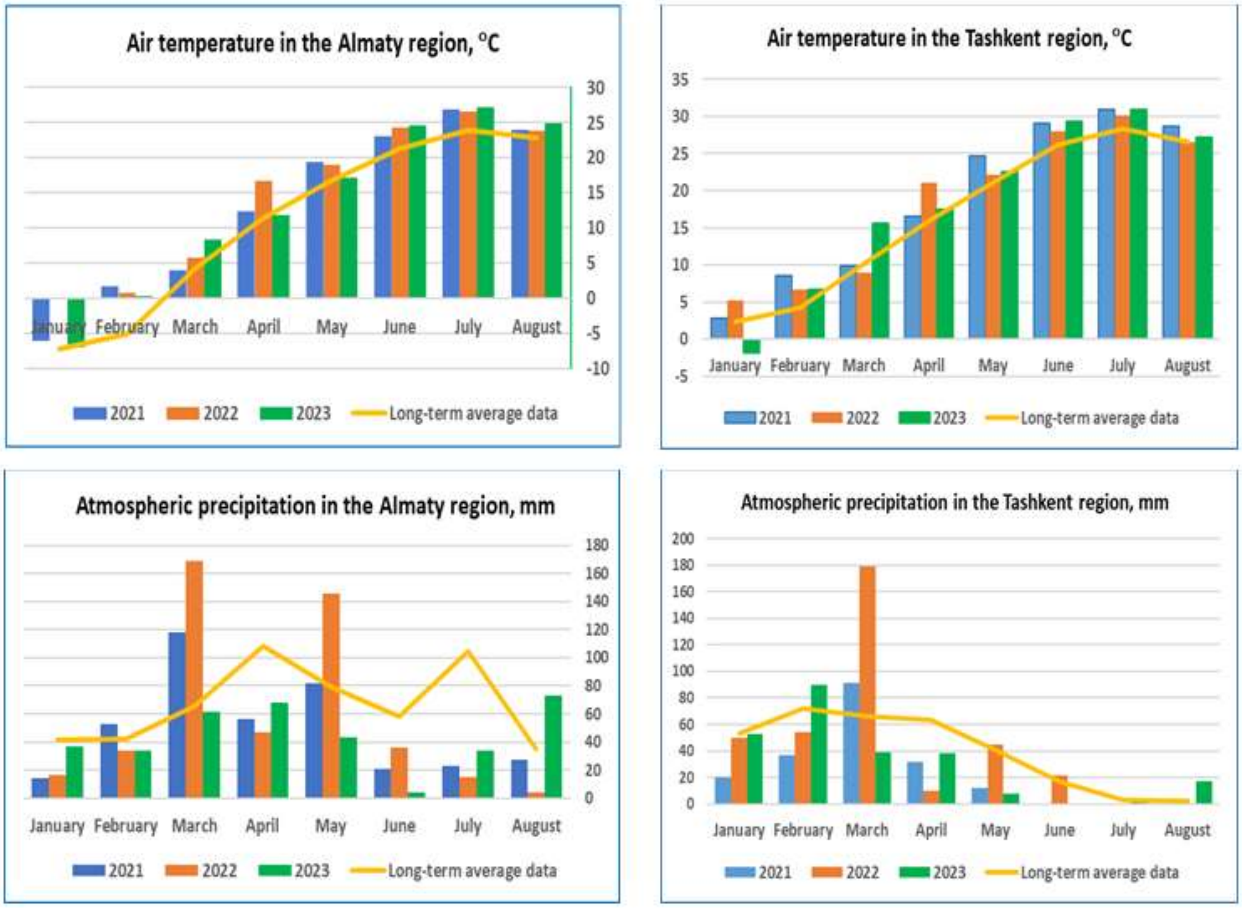

Figure 1. Changes in air temperature and precipitation in Kazakhstan and Uzbekistan.

Winter wheat can efficiently utilize soil moisture in autumn, winter, and spring, including precipitation in the first half of summer, growing in a suitable temperature regime. Grain yields of well-overwintered winter wheat are usually 2–3 times higher than yields of the spring wheat. Winter wheat also suffers from drought in severe dry seasons; however, some cultivars showed tolerance to soil and atmospheric drought.

In winter wheat, the chief characteristics of drought tolerance are the high number of tillers, short growing season, sturdy root system, average plant height, long upper stem internode, small flag leaf area, leaf rolling, waxy patina, and physiological and biochemical reactions of plants during drought conditions. Studying these indicators and their utilization in wheat breeding is vital in selecting drought-tolerant genotypes (Varga *et al.,* 2013; Albayrak *et al.,* 2021). Drought tolerance is a complex and polygenic trait, with various environmental elements influencing its expression. Physiological reactions include stomatal closure, decreased photosynthesis activity, impaired cell wall integrity, loss of turgor and osmosis regulation, lessened leaf water potential, stomatal conductivity, and growth rates (Nezhadahmadi *et al.,* 2013). Thus, the study of criteria for drought resistance of winter wheat, such as the flag leaf parameters, leaf rolling during drought, slowing the aging of 'Stay-green,' plant desquamation, and waxy patina, allows for selecting valuable varieties under climate change conditions toward aridity.

MATERIALS AND METHODS

The prime research sources were winter wheat cultivars planted in Kazakhstan and Uzbekistan. Field experiments in Kazakhstan began at the Karoi Nursery in the Almaty Region and the Institute of Genetics and Experimental Plant Biology, Tashkent Region, Uzbekistan. The current research on drought tolerance in winter wheat (*T. aestivum* L.) included the following stages: a) study of seedlings in laboratory conditions, b) study of drought tolerance in natural drought conditions, c) determination of grain yield under drought conditions, d) assessing grain and baking qualities, and e) drought tolerance determination in plants.

Examination of seedlings under laboratory conditions

Laboratory evaluation of wheat seedlings for drought tolerance typically started using sucrose osmotic solution between 10–20 atm. A high percentage of germinated seeds reflects the cultivar's ability to utilize the limited moisture reserves in the soil and its drought tolerance during the initial stages of development. The main advantage of this technique was its simplicity and high throughput. This method allows mass evaluation of the initial breeding material's drought tolerance under laboratory conditions.

Study of drought tolerance under natural conditions

Evaluating wheat drought tolerance continued in natural drought conditions and special nurseries comprising a developed drought model 'dryland' occurs. Under such conditions, water retention capacity, leaf area, and morphological and physiological characteristics of winter wheat identification transpired. Breeders usually establish special nurseries under natural arid conditions and conduct a comprehensive study of the breeding material, from the field germination of seeds to grain parameters of the resulting crop.

Determination of yield under drought conditions

Under field conditions, wheat plants' performance indicators, such as the number of spikelets, flowers per spikelet, grains per spikelet, 1000-kernel weight, and grain yield, were usually notable. In wheat cultivars, grains per ear, 1000-kernel weight, and grain yield were more drought-sensitive than plant height and spikelets per spike. Under drought conditions, locally adaptive cultivars generally have less grain yield loss than in optimal conditions (Dencic *et al.,* 2000). The presented studies successfully identified the breeding lines combining high drought tolerance with productivity indicators under field drought conditions.

Study of grain quality and baking qualities

Developing drought-tolerant wheat cultivars with better grain quality involves probing their quality parameters using appropriate methods and indicators. The chief traits in breeding for quality are nature, vitreousness and moisture content of grain, quantity and quality of protein and gluten, sedimentation in acetic acid, flour physical analysis, physical properties of dough, and baking test.

Drought tolerance determination in plants

Currently, several coefficients and indices are applicable in drought resistance. The often-used indicator of meteorological studies is the hydrothermal humidification coefficient (HTC) by G.T. Selyaninov, which is the ratio of the sum of precipitation for at least a month to the sum of temperatures above 10 °C for the same period, reduced by 10 times. Classification of humidification zones by HTC scores at wet (1.6–1.3), slightly arid (1.3–1.0), arid (1.0–0.7), very arid (0.7–0.4), and dry (<0.4) (Ionova *et al.,* 2019). Fischer and Maurer (1978) proposed the Drought Susceptibility Index (DSI). Rosielle and Hamblin (1981) developed the Medium Plant Productivity (MP) during drought and Tolerance (TOL) of

Table 1. Equations for determination of the drought tolerance in wheat plants.

Indexes	Equations	Source
Hydrothermal humidification coefficient (HTC)	$HTC = R \times 10 / \Sigma t$	Ionova *et al.* (2019)
Drought Tolerance Index (DTI)	$DTI = (Yp) \times (Ys) / (Yp\text{-})^2$	Fernandez (1992)
Drought Susceptibility Index (DSI)	$DSI = (1\text{-} (Ys/ Yp) / (1\text{-} (Ys\text{-} / Yp\text{-})$	Fischer and Maurer (1978)
Medium Plant Productivity (MP) during drought	$MP = (Yp + Ys) / 2$	Rosielle and Hamblin (1981)
Drought tolerance (TOL) of genotypes	$TOL = Yp - Ys$	Rosielle and Hamblin (1981)
Modified Stress Tolerance Index (MsSTI)	$MsSTI = (Ys)^2 / (Ys\text{-})^2 \times DTI$	Farshadfar and Sutka (2002)

R – Sum of precipitation in millimeters for the period with temperatures above +10 °C, Σt – sum of temperatures (°C) for the same time.

Yp – yield under optimal conditions, Ys – yield under drought conditions, Yp- – average yield under optimal conditions, Ys- – average yield under drought conditions.

genotypes to drought. Meanwhile, Fernandez (1992) proposed the Drought Tolerance Index (DTI). Farshadfar and Sutka (2002) introduced a correction factor to DTI and proposed the Modified Stress Tolerance Index (MsSTI). These indices considered characteristics of the genotypes under optimal and stressful conditions to identify the susceptible genotypes from tolerant ones. The equations for calculating drought tolerance indices used to assess the effect of drought on yield and select drought-tolerant genotypes are available in Table 1.

Thus, various methods of determining the drought tolerance of winter wheat exist today. However, the primary ones are the study of seedlings in the laboratory, study under natural conditions and 'drylands,' yield measurement under drought conditions, and grain and baking qualities tests. Therefore, the equations used to determine the plant's drought tolerance are crucial.

RESULTS AND DISCUSSION

Drought tolerance criterion of winter wheat

Flag leaf parameters

Wheat (*T. aestivum* L.) morphological traits play an influential role during drought. According to a past study, the chief morphological features of drought tolerance are leaf (shape, length, area, size, pubescence, and wax plaque) and root (dry mass, density, and length) parameters (Dencic *et al.*, 2000). Under drought conditions, high-yielding winter wheat cultivars were prominent with the high dry mass of flag leaf at the flowering stage. A positive relationship between grain productivity of the winter wheat's main shoot spike and yield and flag leaf dry mass at the flowering phase has reached detection (Morgun *et al.,* 2022). According to researchers, wheat yield appeared positively associated with the flag leaf area, ear length, grains per spike, grain weight per spike, and 1000-kernel weight. A positive correlation also occurred (r = 0.59) between the main spike grain weight and the duration of the two upper leaves after heading (Lepekhov and Korobeynikov, 2012).

Numerous researchers believe that flag leaves and awns' contributions were more than 40% in forming grain weight per spike in wheat (Akmal *et al.,* 2000). Flag leaf area has long served as a selection criterion for drought tolerance in various crops (Fischer and Maurer, 1978). A strong correlation existed (r = 0.71) between yield and flag leaf area, and a medium correlation (r = 0.68) between grain yield and the area of the second leaf from the top, with both leaves almost equally determined by the grain yield. In the North Caucasus conditions, wheat cultivars with flag leaf areas greater than 20 cm^2 have the maximum grain yield (Gudkova, 2008). A report has also proven that grain yield depends on the leaf size, their location in space relative to each other, and the scale size and spike awns (Gromova and Kostylev, 2018).

Usually, in wheat cultivars, the flag leaf area varies widely (10–40 cm^2), and grain yield is independent of the flag leaf area. Plants with large and small leaves form high yields.

Table 2. Productivity indicators of winter wheat in Karoi Nursery, Almaty Region, Kazakhstan, 2023.

Cultivar name, country*	Flag leaf length (cm)	Flag leaf width (cm)	Flag leaf area (cm^2)	Spikelets spike^{-1}	Spike weight (g)	Grains (g/m^2)	Grain weight (g/m^2)	1000-kernel weight (g)
Steklovidnaya 24, KZ	11,7	0,9	7,00	16,0	64	5180	136	26
Vavilov, KZ	12,7	0,9	7,88	12,7	72	7352	184	24
Dimash, KZ	16,7	0,9	10,37	13,0	64	5712	168	28
Egemen 20, KZ	15,2	1,0	10,11	17,0	86	7112	200	28
Faraby, KZ	14,0	0,9	8,71	15,0	56	4724	104	22
Nesipkhan, KZ	19,3	1,0	12,46	12,3	80	6340	184	28
Talimi 80, KZ	14,0	0,9	8,09	16,3	68	6312	152	24
Gozgon, UZ	13,3	1,0	8,89	14,3	58	4876	144	30
Euclid, FR	12,3	0,7	5,48	12,7	50	4532	88	20
Bezostaya 100, RU	14,3	0,8	7,33	13,3	64	8464	168	20

*KZ – Kazakhstan, UZ – Uzbekistan, FR – France, RU – Russia.

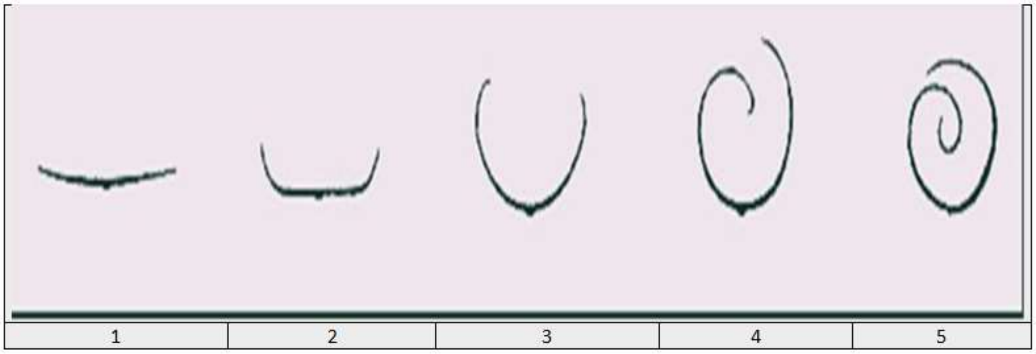

Figure 2. Reference scale for assessing leaf roll (O'Toole *et al.,* 1979).

However, in winter wheat cultivars under natural drought conditions (Karoi nursery, Almaty Region, Kazakhstan), the length and width of the flag leaf were minimal, and accordingly, the calculated flag leaf area was in the range of 5.48–12.46 cm^2. In the promising study, the cultivars with high flag leaf indices correlated with high grain productivity (Table 2).

Table 2 data showed that under severe natural drought conditions, the local drought-tolerant winter wheat cultivars, Vavilov, Dimash, Egemen 20, Farabi, and Nesipkhan, had the highest indicators of ear productivity and grain yield. In connection with the intensification of drought in the region, winter wheat cultivars with optimal vertical leaves able to withstand long droughts and produce a higher grain yield were promising.

Leaf rolling during drought

Leaf rolling is a beneficial trait of wheat that helps to move atmospheric water to the root zone. In wheat genotypes, the dynamics of leaf rolling support high resource utilization efficiency, which can compensate for yield losses under drought conditions (Ali *et al.,* 2022). Leaf rolling is one of the traits that commonly prevail in modern cereal breeding programs for drought tolerance. Currently, in cereal crops, the leaf rolling receives ratings on a 5-point scale (O'Toole *et al.,* 1979) (Figure 2).

Plant leaf rolling prevents leaf damage, reduces transpiration by reducing leaf area, and increases water use efficiency. Water deficit conditions, increased temperature, and solar radiation enhance the leaf rolling in plants, raising drought tolerance. Under moisture deficit conditions, leaf rolling has a positive effect on plants by limiting water loss through the stomata and leaf expansion (Ben-Amar *et al.,* 2020).

Slowing the aging of 'Stay-green' plants

The stay-green trait has become a key indicator of stress adaptation. The ability to retain a green appearance (delayed senescence) at the grain-filling stage implied association with high chlorophyll content in leaves at flowering (Reynolds and Trethowan, 2007). The definition of this index as the NDVI index at physiological maturity may have a cumulative effect on other traits in improving stress adaptation. It has also been an option that delayed leaf senescence may prolong the grain filling and, thus increase the wheat yield. The wheat plants with delayed leaf senescence produce 40% more photosynthesis than the control. However, they have the same rate and duration of starch accumulation during grain-filling and 1000-kernel weight (Borill *et al.,* 2015).

Wheat plants with delayed leaf senescence are preferable in various breeding programs because they considerably increase resistance to disease and drought conditions (Munir *et al.,* 2007). Greener cultivars with high NDVI values, and two weeks after flowering can maintain grain yield under heat-stress conditions. However, this property weakens with extremely high temperatures associated with arid conditions. It revealed that genotypes that remain green were more productive under stressful conditions than aging plants. Maintaining the green color is a promising sign for improving the wheat's resistance to heat stress after flowering.

Plant desquamation and waxy patina

The cuticle structure of wheat plays an essential role in regulating water loss. An indicator of cuticle development is leaf and stem sisalation. The sisalation is a visual trait with easy assessment, and some breeders consider this trait an important selection objective. The relationship between cuticle and drought tolerance is not simple, and graying (sisalation) is not a unique tolerance indicator. Rather, specific wax composition affects moisture loss by leaves under water deficit conditions. These features of cuticle composition and deposition appear vital and should serve as beneficial selection criteria (Bi *et al.,* 2017).

Breeding for drought tolerance

The development of drought-tolerant cultivars for different ecological zones through extensive use of different accessions is the key figure of drought management. Plant breeders have significantly improved wheat adaptation to environmental temperature stress worldwide. This progress has largely succeeded through empirical breeding and genetic variability in the wheat gene pool, where sufficient genetic variability exists to ensure wheat adaptation to abiotic stresses (Trethowan and Mujeeb-Kazi, 2008). However, despite the research aimed at developing cultivars tolerant to heat, drought, and agro-technologies, crop productivity remains low. Given the importance of drought on a global scale, CIMMYT (International Maize and Wheat Improvement Center) has established the Consortium for Improving Heat and Drought Tolerance in Wheat (HeDWIC). One of the consortium activities is the consistent improvement of the capacity of wheat breeding to respond rapidly to climate change threats (Reynolds *et al.,* 2021).

Drought tolerance is very challenging, requiring more research on this abiotic stress. Advances in three main areas of science drive progress in understanding drought tolerance. These are research on physiological, breeding, and genetic aspects. In doing so, breeders and geneticists must select the cultivars that can maintain photosynthetic apparatus and photochemical efficiency under water deficit conditions. In practical breeding, often the traits, such as leaf rolling, keeping plants green, and leaf wilting, are simple physiological assays with visual evaluations. An invaluable physiological trait that provides a quick measure of plants is NDVI. The vegetative index can help predict the wheat grain yield as there is a strong correlation of NDVI with wheat grain yield at growth stages. Evaluating wheat genotypes capable of maintaining green appearance at late stages helped select cultivars with high heat tolerance (Babar *et al.,* 2006; Reynolds and Trethowan, 2007).

According to Lan *et al.* (2022), it is necessary to study the genetic diversity of breeding lines for the last century to find sources of abiotic stresses. Old genetic materials are the unused resources to find candidate genes that contribute to high yield under stress conditions. Lepekhov (2022) reviewed the results using the infrared thermometer in plant breeding and described the main advantages and disadvantages of CTD (Canopy Temperature Depression) assessed by the infrared thermometer. The CTD evaluation is a reliable, technically simple, and productive process. If properly used, can objectively determine the aspects of heat and drought tolerance in cultivars while keeping the plants alive, and that distinguishes it from other methods.

Thus, drought tolerance in winter wheat is a global concern. Despite some achievements, the drought tolerance and identification of wheat genotypes with resistance traits are very relevant for Kazakhstan and Uzbekistan, located in the arid continental region.

Drought tolerant cultivars in Kazakhstan and Uzbekistan

In Kazakhstan, the breeders pay much attention to developing drought-tolerant wheat cultivars, as almost 85%–87% of wheat crop cultivation is on rainfed lands. Currently, the most drought-tolerant winter wheat cultivars commercially grown in these regions are the following:

VAVILOV: Type – *erythrospermum* with a 100–110 cm plant height and an average yield of 5.98 t/ha. Grain quality is high, and other traits include 1000-kernel weight (44.2 g), test weight (805 g/l), protein (15.9%), gluten (36.4%), and bread volume (783 ml). The cultivar is moderately resistant to yellow and leaf rust. Their approval for use began in 2021 in Zhambyl and Turkestan regions under irrigated and moisture-rich rainfed conditions.

DIMASH: Type – *erythrospermum* with a 110–115 cm plant height. The cultivar is medium-early and heat and drought-tolerant. Under rainfed conditions, its average yield is 5.07 t/ha. Grain quality is high, with 1000-kernel weight at 46.1 g) and test weight at 786 g/l). It passed production in 2021 in the Zhambyl Region, possessing high adaptability.

EGEMEN 20: Type – *erythrospermum* tolerant to drought, lodging, and shattering. In the Almaty Region, its grain yield amounted to 3.5 t/ha, while in the Turkestan Region, 5.1 t/ha. Other vital traits measurements were 1000-grain (kernel) weight (39.1–46.5 g), gluten (29.5%), protein (13%–14.2%), and bread volume (890–970 ml). Since 2016, the said cultivar’s approval for cultivation has ensued in Almaty and Turkestan regions.

STEKLOVIDNAYA 24: Type – *erythrospermum* with highest heat and drought tolerance. Grains at maturity do not crumble and are well-threshed. Its average yield is 3.5 t/ha under rainfed conditions, and in irrigated conditions, it yields up to 7.0 t/ha and even higher. The other variables are 1000-kernel weight (44–48 g) and test weight (750–790 g/l). By grain quality, it attained enlistment as high-grade wheat genotypes. The said cultivar is resistant to loose smut and common bunt and tolerant to spring frosts. Since 1995, its cultivation has continued on the rainfed and limited irrigated lands of Almaty, Zhetysu, Zhambyl, and Turkestan regions, as well as in Kyrgyzstan, Tajikistan, and Turkmenistan.

SHOL: The said cultivar is resistant to lodging with a 103–118 cm plant height. It is distinctive and tolerant to drought and spring frosts. It also has characteristics of complex resistance to local races of leaf and yellow rust, loose smut, and common bunt, with an average yield of 3.03 t/ha. Its 1000-kernel weight is 40.8–49.0 g, and the test weight is 757–820 g/l. Its grains per main spike are 45.5–60.5, with productive tillers of 2.2–2.8 pcs. Since 2020, the said cultivar has reached approval for cultivation in the Turkestan Region.

In Uzbekistan, it is a well-known winter wheat mainly sown in irrigated conditions, avoiding severe abiotic stresses during the growing season. However, in recent years, another problem has appeared in the Republic – heat, and sometimes, abnormal heat in the ripening phase of winter wheat. The flowering phase of winter wheat cultivars in the central and northern regions of Uzbekistan begins in early May and lasts until May 10, sometimes until May 15. Heat starts in the last 10 days of May or early June in the phase of waxy ripeness. With strong heat, the accumulation of starch and protein in the grain deteriorates, resulting in low-quality grain unsuitable for baking. It forces the breeders to work with the problem of age-related drought tolerance, not under laboratory conditions, but under controlled conditions or in field nurseries.

In Uzbekistan, the following winter wheat cultivars are the most heat- and drought-tolerant under irrigated conditions:

PAHLAVON: Type – *erythrospermum*. The cultivar is tolerant to water deficit conditions and soil salinity and moderately resistant to rust diseases. It is distinct from other cultivars with features well adapted to local conditions, medium maturity, height (100–110 cm), medium resistance to lodging, and high baking quality. Moreover, the quality of straw is high and soft, which makes it a possible fodder for livestock. Its other vital traits are productive tillering (7–10), 1000-kernel weight (52–56 g), and test weight (850–870 g/l). Its average yield is around 7.0 t/ha, with gluten (28%–30%) and a 65 gluten deformation index. Baking quality is high, especially for tandoor bread.

BARDOSH: Type – *graecum*, characterized by resistance to yellow rust. The cultivar has nonspecific age resistance, which provides long-term preservation of this resistance in production conditions. Although the cultivar is of semi-intensive type, however, under optimal cultivation conditions, the average yield amounted to 8.0 t/ha. The said cultivar is relatively drought-tolerant, does not require abundant watering during vegetation, and is moderately responsive to fertilizers.

OK MARVARID: Type – *graecum*. The said cultivar is tolerant to drought, especially in the ripening phase, and has an average lodging resistance. Its other crucial traits are 1000-kernel weight (41 g), gluten (29.0%), protein (14%), average yield (6.3 t/ha), potential yield (8.0 t/ha), test weight (821 g/l), and gluten deformation index, 65.

EZOZ: Type – *graecum*. Highly tolerant to drought and resistant to yellow rust. The said cultivar is semi-intensive, but the average yield reaches up to 8.0 t/ha under optimal cultivation conditions. Gluten is 30%–32%, and a gluten deformation index is around 65–75, which ensures a good quality flour yield.

SHAMS: Type – *graecum* and highly tolerant to drought. The said cultivar is semi-intensive, but the average yield reaches up to 8.0 t/ha under optimal cultivation conditions. It is facultative wheat-handed (can be sown in the fall and spring) and medium ripening. Grains at maturity do not crumble, and well-threshing is easy.

CONCLUSIONS

In 2021–2023, the increased air temperature during the growing season in the winter-sown regions of Kazakhstan (1.73 °C–2.60 °C) and Uzbekistan (1.97 °C–2.57 °C) transpired with the decreased precipitation compared with the past average data. Precipitation is often uneven during the plants' growing season. Studying drought resistance in winter wheat (*T. aestivum* L.) in these countries is imperative. Considering climate warming in the region, it is necessary to research winter wheat drought tolerance for productive tillers, vegetation period, plant height, length of the upper stem internode, flag leaf area, leaf rolling, waxy patina, and physiological and biochemical reactions of plants during drought conditions.

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