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BREAD WHEAT RESPONSE TO HEAT STRESS CONDITIONS FOR PRODUCTIVITY IN THE SOUTHERN REGIONS OF UZBEKISTAN

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SUMMARY

Climate change and enhanced air temperatures adversely affect the wheat's (*Triticum aestivum* L.) morphological, physiological, biochemical, and molecular properties and grain yield. Therefore, developing high-yielding and resistant bread wheat cultivars to abiotic factors is vital, along with their primary source under varied environmental conditions. In the presented study, monitoring the influence of high temperatures (30 °C and above) continuously during the grain maturation period, especially in grain filling, on grain quality and productivity has undergone thorough research in the southern parts of Uzbekistan. These Southern regions mainly grow winter bread wheat cultivars. In determining the heat resistance of winter wheat cultivars typically planted in the Republic and selecting the best ones, the experiments and observations materialized with optimum and late-sowing conditions. The study determined the temperature during the growth period and daily temperatures during the grain-filling period. The research was able to evaluate the influence of air temperatures on growth phases, plant height (cm), spike length (cm), spikelets per spike, grain weight per spike, 1000-grain weight, grain nature, and protein and gluten content and compare the results under optimum and late periods.

Keywords: Bread wheat (*T. aestivum* L.), cultivars, climate change, high temperature, heat resistance, growth phases, grain-filling period, grain yield and quality

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Key findings: In wheat (*T. aestivum* L.) cultivars with late sowing, the spiking stage began 9–10 days later than the optimum sowing. Grain yield decreased by 1.53– 2.76 t/ha and 1000-grain weight by 0.25–9.85 g due to a rise in temperature during maturation. Heat-susceptible cultivars manifested a sharp decline in their productivity.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is the most internationally valuable and chief cereal crop. Bread wheat croplands cover 17% of the total crop area, with 704 million tons of wheat grains produced yearly worldwide. Regarding global climatic changes, more attention needs to center on the increase in grain productivity through developing wheat cultivars tolerant to abiotic factors in cereal-producing countries, such as the United States, Canada, China, India, and Russia (Buronov and Xamroev, 2022; Buronov *et al*., 2023). One of the crucial tasks in food security is improving cereal crop productivity and quality (Baboev *et al*., 2017, 2021). Several factors influence wheat cultivar growth, development, and productivity in the last spring and summer months (Amanov *et al*., 2020, 2022).

Producing good quality, high-yielding cultivars with resistance to various external stress conditions and wheat hybrid evaluation is essential and relevant (Muminov *et al*., 2023). Large-scale measures progressed to develop agriculture after gaining independence, including grain crop development, and as a result, achieving independence in grain crops took a short time. Likewise, special attention should focus on creating wheat cultivars tolerant to abiotic factors—drought, heat, and hot wind conditions (Qulmamatova *et al*., 2022; Omonov *et al*., 2023).

According to the Food and Agriculture Organization (FAO) and the International Maize and Wheat Improvement Center (CIMMYT), the demand for food, including grain crops, has been increasing for years worldwide. It is due to the community’s need for 60% of protein through cereals, which will further rise. Globally, the area of grain crops is 840 million hectares, of which 227 million hectares is wheat cropland. Wheat, cultivated as the main crop, occurs in about 180 countries. However, its productivity is much lower than the potential level of 2.71 t/ha, which hardly meets 60% of the population's grain needs. Today, the European Union is the largest wheat producer (123 million tons), followed by China (96 million tons), India (72 million tons), the USA (68 million tons), and Russia (63 million tons). The largest grain consumers are the European Union (EU) countries (120 million tons), China (100 million tons), and India (75 million tons) (www.statista.com).

According to the decision of the State Commission for Testing Agricultural Crop Cultivars of the Republic of Uzbekistan, more than 40 bread wheat cultivars have been included in the State Register, with more than 20 genotypes considered local cultivars developed under local conditions. The spiking stage of winter wheat takes place in Uzbekistan’s dry and hot seasons. Rainfall in late April and early May almost does not affect the winter wheat yield. During this period, precipitation is low, moistening only the soil surface. Flowering and pollination occur naturally at a temperature of 11 °C–30 °C. However, when the air temperature is 20 °C–25 °C, these processes accelerate. If the soil has enough moisture and the air temperature is 25 °C–30 °C, flowering and pollination remain normal. The spiking, flowering, and pollination duration varies from 5–8 days to 10–12 days (Beknazarov, 1999). Drought and high temperatures affect up to 40% of the late-sown wheat fields (Buriro *et al.*, 2011); however, drought resistance did not occur at the same rate throughout the wheat-growing period. Studies showed that photosynthesis in the awned spikes occurred twice, and the awns developed later and preserved photosynthetic activity indicating the genotypes as drought resistance (Reynolds and Arias, 2001). Abiotic heat stress can reduce photosynthetic capacity, imbalance between plant and water relations, hormonal imbalance, decreases of metabolic activities, production of oxidative reactive species, male sterility, reduction of pollen tube development, and promotion of ethylene production in wheat (Almeselmani *et al*., 2011; Oshino *et al*., 2011; Ashraf *et al*., 2013).

In developing countries, 32% of wheat cultivars bore exposure to heat during the growing season (Sinha, 1985). Local-type wheat cultivars grown in Central Asia are heat-resistant. Detrimental temperatures that cause coagulation of protein in the plant are around +55 °C to +56 °C at the early growth phase of the plant, while at the spiking and grain-filling phase, it can be at +61 °C (Qulmamatova *et al*., 2022). If the temperature and humidity are high during the wheat flowering period and the plants stay at 30 °C temperature for three days, the flowers will be infertile, reducing the grains by 68% (Yakubjonov *et al*., 2009). The optimum air temperature for wheat growth emerged to be 18 °C–24 °C. However, when air temperature reaches 28 °C–32 °C for 5–6 days, there is a 20% drop in productivity (Teal *et al*., 2006).

In the case of high yields, reports revealed the lines KRBW17-6 and UZ15PC-58 were with higher performance than the standard cultivars (Dilmurodovich *et al*., 2021; Juraev *et al*., 2023a, b). Based on the above discussion, the effects of environmental factors on grain yield and quality traits in winter wheat incurred studies in the southern regions of Uzbekistan. In particular, the study determined the effect of heat by planting optimally and late in different areas (Amanov *et al*., 2021). Inheritance of characters in bread wheat hybrids and their selection with valuable traits ensued (Juraev *et al*., 2021a, b; Bekmurodovich *et al*., 2023).

MATERIALS AND METHODS

Wheatfield experiments commenced from 2012 to 2014 at the Kashkadarya Branch of the Research Institute of Grain and Leguminous Crops, Uzbekistan. Laboratory experiments continued in the laboratory 'Determination of Technological Quality and Physiology of Grain Quality.' Experimental positioning and phenological observations, calculations, and analyses transpired during the experiments (All-Union Institute of Plant Industry - VIR, 1984), with biometric analyses conducted according to the methods of the State Testing Commission on Crop Cultivars (1985, 1989). Technological characteristics of winter wheat grains cultivated in the experimental field underwent comparison with the data of manuals (Methodological recommendation for the evaluation of grain quality and Methods of biochemical study of plants) with gluten content (GOST 13586-1-68), grain glassy color (GOST 10987-76), grain moisture (GOST 13586-5-93), grain nature (GOST 3040-55), and 1000-grain weight (GOST 10842-89). All the statistical analyses depended on Dospekhov's methods (1985).

The field experimental research applied the randomized complete block design and Alpha lattice design of the Genestat-3 program. The 105 wheat cultivars reached planting in the optimum (October 15) and late (November 15) sowing periods, undergoing comparison and evaluation for heat resistance. Studying the influence of heat progressed during the grain proliferation period on productivity parameters of late-sown wheat genotypes.

The leaf chlorophyll content measurement on a SPAD meter device occurred every 10 days after the spiking phase. Determining green color variations in the wheat plants on the GreenSeeker device ensued every 15 days after the shooting stage, and it measures the plant's green parts using infrared radiation. The numbers displayed on the monitor are the normalized difference of the vegetative index (NDVI). This instrument measures the chloroplasts in the plant body on a scale of 0.1 to 1.0. The higher the scale number, the greater the plant body has chloroplasts, i.e., the green mass, which is crucial in developing harvest elements. Notably, the correlation between NDVI and wheat grain yields was the highest at the time of nodes and flag leaf formation on wheat plant stems.

RESULTS AND DISCUSSION

In the study of wheat cultivars with optimum and late-sown periods, the spiking-maturation period varies accordingly during the different crop seasons. The shortest spiking-maturation phase was evident in the experiments during 2012 and 2014. It may be because spring has an average daily temperature much higher during these years than in other crop seasons. The highest daily temperature data appeared during the spiking-maturation stage. The sum of the temperatures obtained by the wheat cultivars during that period and the average daily temperature reached calculations. However, the late-sown period due to the late beginning of the spiking stage and rapid maturation under intense heat effects shortened the spiking-maturation period.

The normalized difference vegetation index (NDVI), a measure of leaf greenness (chlorophyll content), seemed to interlink with crop productivity. The genotypic variations for NDVI at different growth stages and their relationship to grain yield in winter wheat under terminal heat stress have been studied (Hu *et al*., 2010). The probe of 30 winter wheat genotypes materialized at two locations during crop seasons 2009–2010 and 2010–2011 in Uzbekistan. The NDVI recordings included booting, heading, milk, and dough stages (Sharma *et al*., 2011). The wheat genotypes differed significantly for NDVI at each stage, while the grain yield ranged from 3.9 to 6.1 t/ha. Wheat genotypes differed in percent decline in NDVI from booting to dough stage (Rosyara *et al*., 2010). The positive correlation of NDVI with grain yield suggested that it could serve as an indirect selection criterion for identifying physiologically superior and high-yielding wheat genotypes under terminal heat stress (Teal *et al*., 2006).

By assessing the temperature effects on the spiking-maturation stage, the study revealed that in 2012, the spiking-maturation stage of bread occurred on warm days in the late period. After May 04, temperatures above 30 °C have affected the productivity parameters of the wheat cultivars. Specifically, after May 30, an increase in temperature up to 35 °C–37 °C led to the rapid maturation of cultivars that were non-resistant to heat. As a result, the short grain-filling period gave a sharp decline in the farm-valuable traits of the cultivars in the late sown compared with the optimum period (Figure 1). According to the results, the spiking-maturation stage of the cultivars constituted 36–50 days in optimum time. It was evident that the spiking stage occurred in the optimum period between April 16 and May 03, while in the late period, between April 28 and May 15. The complete maturation period was prevalent on June 02–09, while the late period was on June 06–17. In these days, the average air temperature was 27 °C–30 °C, while the highest air temperature was 35 °C–39 °C. With such high temperatures, the rapid maturation of wheat cultivars was visible.

Based on the results, the standard wheat cultivar Krasnodar-99 transitioned to the full spiking phase under optimum planting conditions on April 27, while under the late sowing was on May 06, with full maturity on June 06, and in late sowing on June 14. The spiking-maturation stage constituted 40 days in the optimum time, while 39 days in the late period. The average temperatures at these times were 964 °C in the optimum period and 1012.2 °C in the late period. The temperature in one day was 24.1 °C in the optimum period, while in the late period it was 26 °C. The grain yield was 5.13 and 3.6 t/ha in the optimum and late periods, while 1000-grain weight was 40.2 and 31.7 g for the optimum and late periods, respectively.

Consequently, the spiking stage began nine days later than the optimum sowing period. As a result of rising temperatures during the spiking-maturation period, one day of temperature was 1.9 °C higher than the experiment sown with the optimum period. The cultivar productivity decreased by 1.53 t/ha and 1000-grain weight by 8.5 g. According to the results, the cultivar KR11-105-43's productivity constituted 7.43 t/ha, and the 1000-grain weight was 47.7 g in the optimum period. Meanwhile, in the late sowing period, these indications were 6.37 t/ha and 42.0 g, respectively, showing a considerable decline (Table 1).

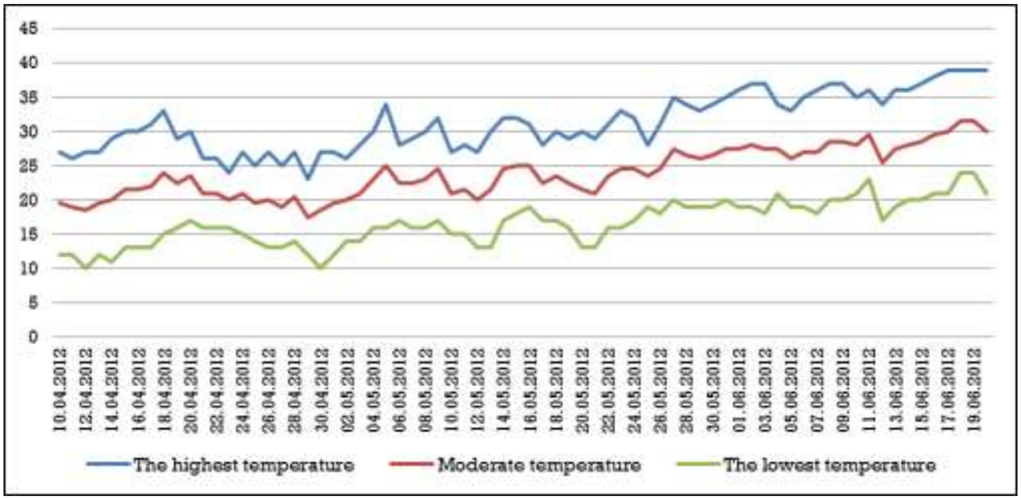

Figure 1. Air temperature at wheat stages of spiking - maturation during 2012.

Table 1. Wheat cultivars with grain yield and 1000-grain weight under optimum and late-sowing conditions (Karshi, 2012–2014).

No.	Cultivars	Optimum period				Late period			
		Grain yield (t/ha)		1000-grain weight (g)		Grain yield (t/ha)		1000-grain weight (g)	
		Average	Difference compared to standard (t/ha)	Average	Difference compared to standard (t/ha)	Average	Difference compared to standard (t/ha)	Average	Difference compared to standard (t/ha)
1	Matonat	5.58±0.57	-4.00	40.6±2.3	0.19	4.71±1.4	0.71	39.9±1.3	0.63
2	KR11-105-11	6.80±0.63	8.20	44.5±3.7	0.59	5.88±1.11	1.88	39.7±1.5	0.67
3	Turkiston	7.22±1.0	12.40	41.9±1.2	0.33	5.69±1.1	1.69	37.0±5.3	0.34
4	Yujnaya-12	5.68±0.62	-3.00	43.4±1.7	0.48	4.94±1.67	0.94	38.6±3.2	0.50
5	Navruz	6.82±0.89	8.40	40.7±2.5	0.20	5.35±1.37	1.35	39.9±0.8	0.63
6	KR11-105-42	6.28±1.19	3.00	44.3±2.9	0.57	5.26±0.36	1.26	36.6±4.4	0.30
7	KR11-105-43	7.96±0.54	19.80	45.5±1.9	0.69	6.39±0.05	2.39	41.2±0.6	0.76
8	KR11-105-44	6.49±0.74	5.10	44.6±4.4	0.59	5.2±0.36	1.20	38.6±1.7	0.50
9	KR11-105-45	6.03±0.6	0.50	44.3±1.8	0.56	5.02±1.33	1.02	37.7±4.0	0.41
10	KR11-105-50	6.80±1.45	8.20	40.5±3.2	0.19	5.37±0.39	1.37	39.3±3.5	0.5
11	KR11-105-59	6.16±0.97	1.80	41.3±1.8	0.26	5.03±0.79	1.03	37.3±3.0	0.37
12	H. Bashir	7.26±0.89	12.80	41.3±1.7	0.26	5.74±0.64	1.74	40.1±1.0	0.65
13	Zarrin	7.33±1.08	13.50	43.2±0.2	0.45	5.87±0.54	1.87	39.9±0.0	0.63
14	Gozgon	7.51±1.0	15.30	44.3±0.5	0.56	6.19±0.49	2.19	40.7±0.7	0.71
15	KR11-105-90	5.91±0.73	-0.70	39.1±2.5	0.04	5.10±0.67	1.10	35.1±2.6	0.15
16	KR11-105-96	5.77±0.74	-2.10	41.3±2.9	0.27	5.07±0.68	1.07	34.5±1.0	0.09
17	Bunyodkor	7.41±0.86	14.30	45.5±2.2	0.68	5.95±0.63	1.95	42.2±0.8	0.86
18	Farovon	7.40±0.98	14.20	40.7±1.0	0.21	5.61±0.5	1.61	40.2±1.0	0.66
19	Barhayot	7.15±1.05	11.70	45.5±2.4	0.69	5.82±0.45	1.82	40.6±1.3	0.70
20	Krasnodar-99	5.98±0.68	0	38.7±2.0	0	4.0±0.33	0	33.6±1.9	0

In 2013, the temperature during the spiking-maturation stage created favorable conditions for selecting heat-resistant cultivars. On April 10–14, the temperature increased to 27 °C–30 °C, and after April 20–22, the temperature rose to 26 °C–31 °C. On May 01–13 and May 14–18, the air temperature reached 25 °C–30 °C and 32 °C–37 °C, respectively. Subsequently, by the end of the spiking-maturation period, the temperature rose to 41 °C (Figure 2). The transition of wheat cultivars sown in the optimum period to the full spiking phase occurred from April 07 to 28. The spiking-maturation stage takes 42–59 days. The average air temperature for this period was 926 °C to 1268.5 °C, while the air temperature for one day was 20.9 °C to 24.3 °C.

The cultivars' productivity showed to be 3.1–8.71 t/ha. The temperature of 30 °C–35 °C and above had a significant impact on productivity. It was clear that in the optimum period, the 1000-grain weight of the cultivars was 32.2–47.4 g. Compared to the optimum period, in the late sown period, the 1000-grain weight was lesser at 13.2 g. On the results for the optimum and late periods, the average spiking-maturation period of the standard cultivar Krasnodar-99 made 45 and 46 days, the total temperature sum was 1014 °C and 1070 °C, the temperature for one day was 22.5 °C and 23.3 °C, the 1000-grain weight constituted 36.2 and 35.5 g, and the productivity was 6.34 and 4.27 t/ha, respectively.

It was evident that the increase in daily temperature (0.8 °C) caused the decrease in the 1000-grain weight by 0.7 g/ha and the productivity by 2.07 t/ha (Table 2). Based on observations in 2014, in April and May, the temperature increased to 26 °C–30 °C on April 19–24. Moreover, from May 01, the maximum temperature was 35 °C and reached 40 °C by June 11. As a –result of the late transition of wheat cultivars sown in the late period into the late-spiking phase and late flowering, this period was at temperatures of 30 °C–35 °C and above. The optimum sowing period of cultivars was from April 16 to May 05 and from April 23 to May 10 (Figure 3). Transition to full maturation phase surfaced in the optimum time, from May 30 to June 08, and in the late sowing period, June 06–12.

The study discovered that in the optimum period, the spiking-maturation stage constituted 34–49 days, while in the late period, 32–46 days. The sum of temperatures of the cultivars during the period of spiking and maturity made 858 °C–1186.5 °C at the optimum time, 811.5 °C–1126.5 °C in the late period, and the average daily temperature was 23.4 °C–25.4 °C at the optimum time and 24.5 °C–25.70 °C in the late period. The grain yield constituted 2.98–7.95 t/ha in the optimum period, while in the late period, the yield was 3.08–6.52 t/ha. The standard cultivar Krasnodar-99's spiking period took 41 days, while in the late period was 40 days, with an average daily temperature of 24.7 °C and 25.6 °C in the optimum and late sowing times, respectively. For the said genotype, the grain yield was 6.48 and 4.14 t/ha in optimum and late sown times, respectively. One can see that the productivity of the said cultivar declined by 2.34 t/ha when the temperature increased by 0.9 °C.

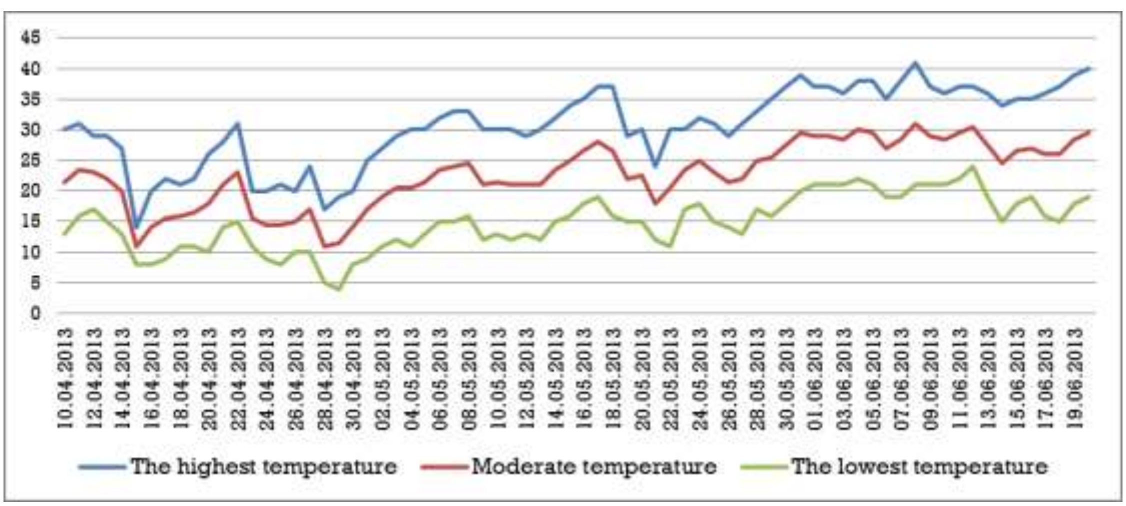

Figure 2. Air temperature at wheat stages of spiking - maturation during 2013.

Table 2. Wheat cultivars with quality traits under optimum and late-sowing conditions (Karshi, 2012–2014).

No.	Cultivars	Optimum time			Late period		
		Protein content (%)	Gluten content (%)	Grain hardness	Protein content (%)	Gluten content (%)	Grain hardness
1	Matonat	13.9±0.9	25.7±2.5	44.8±15.7	12.6±0.9	24.3±0.8	43.6±9.4
2	KR11-105-11	15.5±1.3	30.4±2.7	58.0±3.0	14.2±0.2	28.3±0.3	59.3±7.5
3	Turkiston	15.6±0.8	30.6±1.2	62.9±3.0	14.2±0.1	28.5±0.1	62.2±2.5
4	Yujnaya-12	16.2±0.7	29.2±3.0	53.1±3.1	13.9±0.4	24.2±1.6	56.6±14.3
5	Navruz	14.9±0.6	30.6±0.7	58.2±8.8	14.2±0.3	27.9±1.5	57.5±6.9
6	KR11-105-42	14.7±0.8	26.7±2.8	58.8±16.8	13.5±0.3	25.1±2.5	58.5±18.8
7	KR11-105-43	15.6±0.7	30.5±0.8	72.3±4.5	14.5±0.2	28.9±0.5	66.4±4.9
8	KR11-105-44	15.1±2.3	27.5±0.6	56.7±6.7	14.2±0.1	26.0±3.1	50.3±13.9
9	KR11-105-45	13.3±0.5	27.0±1.0	51.0±7.9	12.4±0.4	25.8±0.3	41.4±6.5
10	KR11-105-50	14.5±1.3	29.6±0.8	56.8±14.2	14.0±0.1	27.0±1.7	57.1±8.9
11	KR11-105-59	14.0±0.2	28.6±1.5	53.2±6.4	12.9±0.3	26.1±2.6	47.3±10.5
12	H. Bashir	15.4±0.5	29.7±0.8	62.3±11.1	14.4±0.2	28.5±0.3	63.2±3.8
13	Zarrin	15.1±1.3	29.3±1.1	62.2±4.7	14.3±0.2	28.2±0.4	61.1±3.3
14	Gozgon	15.4±0.9	29.6±0.5	63.2±13.1	14.3±0.2	28.2±0.2	66.5±5.0
15	KR11-105-90	15.1±0.4	28.5±0.9	60.7±7.9	12.2±1.1	23.7±1.6	38.3±10.0
16	KR11-105-96	13.6±0.8	27.6±1.6	52.1±4.3	12.7±0.7	25.5±0.5	50.1±15.3
17	Bunyodkor	16.0±0.6	29.8±0.9	69.6±4.8	14.5±0.4	28.4±0.3	63.3±6.6
18	Farovon	15.2±1.0	29.4±0.5	66.2±3.3	14.2±0.2	28.5±0.1	63.5±6.8
19	Barhayot	15.1±0.9	28.7±0.3	66.9±4.8	14.3±0.4	28.4±0.1	61.9±4.2
20	Krasnodar-99	14.0±1.1	28.0±0.4	54.8±8.4	13.1±0.2	26.3±0.9	47.2±15.3

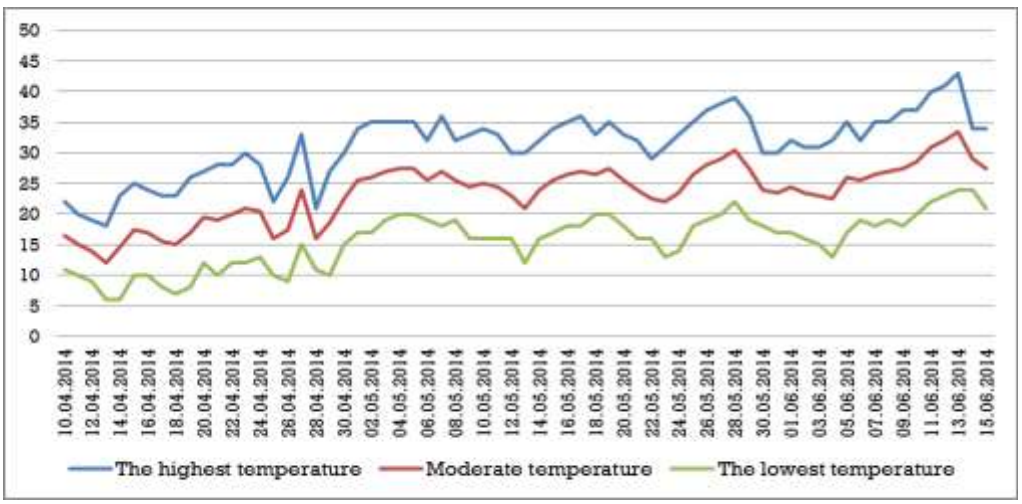

Figure 3. Air temperature at wheat stages of spiking - maturation during 2014.

The results further revealed a significant positive correlation between the spiking-maturation length and the grain-quality characteristics, protein (r = 0.11), and gluten content (r = 0.24). The study also noted the positive correlation (r = 0.03) between the grain yield and the spiking-maturation period of the cultivars sown in the late period. A considerable positive correlation (r = 0.07) of the spiking-maturation period appeared with the 1000-grain weight and a positive correlation between the spiking-maturation period and the protein (r = 0.05) and gluten content (r = 0.06). By analyzing the three-year results, the cultivars KR11-105-43, KR11-105-44, KR11-105-45, KR11-105-50, KR11-105-59, Gozgon, Turkiston, Bunyodkor, Farovon, Barhayot, and KR11-105-42 have the short spiking-maturation stage and high yield; hence, they were the best samples selected.

Productivity indicators of the studied cultivars showed some have high yields and almost the same productivity in both optimum and late periods. Productivity parameters of studied cultivars under the optimum sowing period varied over the years with the influence of weather conditions. The grain yield was 2.06–7.43, 3.10–8.71, and 2.98–7.95 t/ha in optimum sowing periods during 2012, 2013, and 2014, respectively. According to the three-year observation results, the standard cultivar Krasnodar-99's productivity was 5.98 t/ha; however, the grain yield of the cultivars KR11-105-43, Gozgon, KR11-105-44, Jayhun, Bunyodkor, Faravon, H. Bashir, Turkiston, KR11-105-50, Dostlik, KR11-105-50, and Navruz proved to be higher than the standard cultivar, with the said high yield also achieved by sowing them in the late period.

Furthermore, studying the productivity correlation also proceeded with various indicators of the studied wheat cultivars grown within the optimum period. The research determined a positive correlation between the productivity and gluten content (r = 0.08), grain hardness (r = 0.14), IDC index (r = 0.06), grains per spikelet (r = 0.27), spikelets per spike (r = 0.35), plant height (r = 0.23), last node length (r = 0.19), protein content (r = 0.26), spike length (r = 0.28), 1000-grain weight (r = 0.03), grain weight per spike (r = 0.10), and spike weight (r = 0.30). In the late sown period, a positive correlation emerged between productivity and 1000-grain weight (r = 0.28), spike length (r = 0.41), grains per spike (r = 0.27), spike weight (r = 0.16), and grain weight per spike (r = 0.19). The results also expressed that higher grain yields could improve the grain quality. In studying the correlation of grain yield with grain quality indicators, the yield revealed a positive correlation with protein content (r = 0.17), gluten content (r = 0.07), and grain hardness (r = 0.41).

Thousand-grain weight is also an essential trait of high productivity and grain quality. The environmental factors, especially during the period of grain filling, have a significant impact on 1000-grain weight. In particular, heat destroys the physiological processes, eventually affecting the grain filling and 1000-grain weight. A massive grain yield reduction could refer to the decline in 1000-grain weight. In the presented study, the decreases in grain yield and 1000-grain weight were comparable to recently published reports in the neighboring regions of West and South Asia (Al-Maaroof *et al*. 2014; Eisa *et al*. 2014; Karaman *et al*. 2014).

Based on the three-year results, the 1000-grain weight of the studied cultivars varied depending on environmental factors. With optimum and late periods, the wheat genotype samples with higher 1000-grain weight were also options for breeding. The 1000-grain weight of the studied wheat cultivars sown in 2012 with the optimum period decreased by 32.14 to 52.01 g, while with late sowing season by 25.5 to 43.7 g, at 6.6 to 8.3 g less compared with the optimum sowing time. The same trend continued in 2013 and 2014. Based on the three data, the 1000-grain weight of the cultivars was 32.15 to 46.16 g and 28.6 to 42.1 g planted with optimum and late periods, respectively. However, the difference in 1000-grain weight among the cultivars varied from 3.5 to 4.0 g. Cultivars Pamyat-47, Farovon, H-147, KR11-105-44, KR11-105-43, Gozgon, KR11-105-50, H. Bashir, Bunyodkor, Navruz, and KR11-105-11 provided higher 1000-grain weights, being further selected and recommended for the crossbreeding in developing heat-resistant genotypes.

Wheat cultivars identified with higher protein content were samples for selection for optimum and late sowing times. In cultivars, the protein content varied over the years depending on environmental factors. According to the three-year results, the genotypes with higher and same protein content became available. Protein content in wheat cultivars with optimum and late periods ranged from 11.7% to 7.0% and 11.7% to 14.9% in 2012, 12.7% to 18.8% and 11.6% to 14.4% in 2013, and 12.0% to 16.4% and 9.9% to 14.7% in 2014, respectively. Heat-tolerant wheat cultivars with higher protein content became choices in both sowing periods.

The highest levels of gluten surfaced in both sowing periods during 2013. The gluten content in the cultivars varied over the years, depending on the weather conditions. In most wheat cultivars, the gluten contents were significantly lower due to heat stress effects during the spiking-maturation period. Meanwhile, some cultivars manifested to be regular. According to results, the gluten content in cultivars with optimum and late sowing periods constituted 23.2% to 33.0% and 23.0% to 29.2% in 2012, 23.2% to 33.8% and 19.5% to 29.9% in 2013, and 20.5% to 31.4% and 21.1% to 29.1% in 2014, respectively. Following the three-year results, the average gluten contents were 24.5% to 30.7% for the optimum period, while 23.2% to 28.9% for late sowing conditions. The wheat cultivars with enhanced protein and gluten content were selected samples over the years. In wheat cultivars, KR11-105-44, H. Bashir, Bunyodkor, Gozgon, KR11-105-43, KR11-105-50, KR11-105-90, KR11-105-42, KR11-105-11, KR11-105-50, and Navruz, the gluten content did not decrease, and their grain quality parameters proved remarkable.

CONCLUSIONS

The results revealed that the longer the wheat spiking and maturation period, the more flowering and grain-filling phases remain under intense heat stress conditions. In wheat cultivars with a late sowing period, the spiking stage began 9–10 days later than the optimum sowing, and the grain yield decreased by 1.53 to 2.76 t/ha, and 1000-grain weight decreased by 0.25-9.85 g due to rise in temperatures during the spiking-maturation stage. The wheat cultivars susceptible to heat declined sharply in productivity and 1000-grain weight. With optimum and late periods, cultivar KR11-105-43 (Shams) produced 1.98 t/ha more yield and 2.39 t/ha, respectively. Results of grain yield in other cultivars for optimum and late periods, cultivar KR11-105-44 had 1.43 and 1.95 t/ha, cultivar KR11-105-50 (Kesh-2016) with 1.42 and 1.61 t/ha, and cultivar Bunyodkor with 1.35 and 1.87 t/ha more than the standard cultivar Krasnodar-99 yield. These wheat genotypes emerged to be resistant to heat stress conditions.

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