RESEARCH ARTICLE

SABRAO Journal of Breeding and Genetics
55 (6) 1930-1940, 2023
http://doi.org/10.54910/sabrao2023.55.6.7
http://sabraojournal.org/
pISSN 1029-7073; eISSN 2224-8978

CLIMATE CHANGE IMPACT ON CHLOROPHYLL CONTENT AND GRAIN YIELD OF BREAD WHEAT (*TRITICUM AESTIVUM* L.)

S.S. BABOEVA[1,2], F.I. MATKARIMOV[1], R.M. USMANOV[1], O.S. TURAEV[1,2,3], M.A. TOGAEVA[4], S.K. BABOEV[1], and F.N. KUSHANOV[1,2,3*]

[1]Institute of Genetics and Plant Experimental Biology, Academy of Sciences of the Republic of Uzbekistan, Uzbekistan
[2]International Innovation Center for Aral Sea basin Under the President of the Republic of Uzbekistan, Karakalpakstan
[3]Department of Genetics, National University of Uzbekistan, Uzbekistan
[4]Department of "The Technology of Storage and Primary Processing of Agricultural Products", Karshi Engineering-Economics Institute, Uzbekistan
*Corresponding author's email: fakhriddinkushanov@gmail.com
Email addresses of co-authors: sbaboyeva@gmail.com, farrux_matkarimov@mail.ru, usmanov_rustam51@mail.ru, ozodturaev@gmail.com, ziyo.ilm@mail.ru, sai-baboev@yandex.ru

SUMMARY

The paper presents the study of bread wheat's chlorophyll content and grain yield traits under changing environmental conditions — optimal water supply and simulated water-deficit conditions. Selecting 15 wheat cultivars from different regions (Russia, Kazakhstan, Kyrgyzstan, Tajikistan, Turkey, and CIMMYT) based on economically valuable characteristics became the specimens for the presented study that evaluated the SPAD indicators in correlation with the grain yield in bread wheat and determined the vital role of genotypes, environments, and genotype by environment interaction effects. The relationship between chlorophyll content and yield parameters under different growing conditions was also well-defined. The results revealed that ecosystems had more influence on the chlorophyll content than the wheat genotypes. Several wheat cultivars with soil moisture tolerance have gained identification, along with the correlation coefficient between chlorophyll content and grain yield under varied environmental conditions of water supply. The study validated the role of genotypes and environments in the manifestation of responses to stress conditions.

Keywords: Bread wheat (*Triticum aestivum* L.), optimum water supply, water-deficit condition, chlorophyll content index, grain yield, correlation coefficient

Communicating Editor: Dr. Osama Osman Atallah

Manuscript received: May 27, 2023; Accepted: October 19, 2023.

Citation: Baboeva SS, Matkarimov FI, Usmanov RM, Turaev OS, Togaeva MA, Baboev SK, Kushanov FN (2023). Climate change impact on chlorophyll content and grain yield of bread wheat (*Triticum aestivum* L.). *SABRAO J. Breed. Genet.* 55(6): 1930-1940. http://doi.org/10.54910/sabrao2023.55.6.7.

Key findings: Climate variability for two years made it possible to determine the wheat genotypes' potential for resistance to abiotic stress conditions. In the studied cultivars, under the relatively dry season, the chlorophyll content was about the readings of SPAD 250 at 10 units less than in the crop season with high humidity at the early wheat phase. An external factor strongly influenced the chlorophyll content, while the specificity of the cultivars was only 12.7%. The other factors, such as, the volume and pubescence of the leaf and the soil conditions, showed an impact of 15.3%.

INTRODUCTION

Climate change in the form of global warming and several perilous hydrometeorological phenomena, such as, flooding and droughts, temperature fluctuations (extremely high temperatures and frosts), and strong winds are rising. It is also likely that climate change will affect the quantity and quality of water resources, negatively influencing agricultural production and public health (Orlovsky *et al.,* 2019). Genotype-environment interaction effects are the utmost causes of cultivars' differences in their performance under varied environmental conditions. Various genotypes react differently to the same situations, and at the same time, the same genotype responds differently to varied ecological conditions (Pradhan *et al.,* 2012; Doroshkov *et al.,* 2016). Moreover, plant species are often characteristic of immense variations in amplitude in botanical features and properties (Kushanov *et al.,* 2022).

Water scarcity and stress conditions are the most widespread abiotic facets maliciously affecting crop plants. About one-third of the land surface is subject to moisture deficiencies, while half of this area is extremely arid. The climate of Uzbekistan is acutely continental, which experiences extreme seasonal changes. Areas with continental climates have colder winters, longer-lasting snow, and shorter growing seasons. The central part of the territory is an arid zone, which is responsible for the dryness of air and soil, as well as, climate variability. Almost 80% of the country's area comprises desert and semidesert zones (Isadzhanov, 2020).

However, in Uzbekistan, crop production is almost entirely on an irrigated agriculture basis. Noteworthily, over-wetting and more humidity can also negatively impact the general conditions of crop plants and their final yield. Breeding for wide homeostasis is essential since the higher adaptability of the genotypes can ensure their stability under varying environmental conditions (Adylova *et al.,* 2018).

Newly developed crop cultivars with an advantage in a particular region are their resistance to biotic and abiotic factors and adaptability to variations in climatic conditions. In Uzbekistan, climate change requires developing wheat cultivars tolerant to water deficit conditions and resistant to waterlogging, as observed in recent years due to heavy rains during the grain ripening season. Given that photosynthetic activity determines plant productivity, its stability under changing environmental conditions, to a certain extent, can characterize a particular genotype as being able to maintain grain yield within specified limits. The photosynthetic pigments, with other internal and external factors, determine a cultivar's biological and economic productivity.

Several studies revealed that the chlorophyll found in leaves, measured with a SPAD chlorophyll meter, showed close linkage with grain yield (Blackmer and Schepers, 1995; Boggs *et al.,* 2003; Maiti *et al.,* 2004). Past studies also enunciated SPAD readings' positive correlations with wheat dry matter yield (Parvizi *et al.,* 2004). Several studies exhibited the possibility of a reliable indication of nitrogen stress and the relationship with relative outputs from SPAD values. A significant positive correlation of SPAD readings was evident with rice grain yield (Earl and Tollenaar, 1997; Fox *et al.,* 2001; Ramesh *et al.,* 2002; Spaner *et al.,* 2005). In this regard, determining the relationship between chlorophyll content and productivity is essential to predict the yield potential of bread wheat under diverse growing environments and determine the breeding values of the individual genotypes.

MATERIALS AND METHODS

Plant material

The experimental material comprising 15 cultivars of bread wheat (Table 1) was a selection from 201 wheat cultivars based on drought resistance from previous research work (Baboyeva *et al*., 2021, 2022). The cultivars, developed for different ecological and geographical regions, included Kazakhstan, Uzbekistan, the Russian Federation, and the Kyrgyz Republic. The presented study started during 2021–2022 at the Durmon Experimental Field Station, Institute of Genetics and Plant Experimental Biology, Academy of Sciences of the Republic of Uzbekistan. The experiment continued in a randomized complete block design (RCBD) with two replications under two water conditions: a) irrigated and b) water deficit (non-irrigated) conditions. The seeding rate was 200 kg/ha, with all wheat genotypes sown in the fourth week of October. Under artificial drought conditions, field irrigation ensued before planting, then non-irrigation followed the entire growing season. The control background received irrigation after sowing and gained three more watering during the growing season.

Table 1. Bread wheat cultivars used in the study**.**

No.	Name	Origin	Collection	Characters
1	Vassa	Russian Federation	IGPEB*	Lutescens
2	Grom	Russian Federation	IGPEB	Lutescens
3	Andijan 4	Uzbekistan	IGPEB	Erytrospermum
4	Pakhlavon	Uzbekistan	IGPEB	Erytrospermum
5	Durdona	Uzbekistan	IGPEB	Lutescens
6	Ezoz	Uzbekistan	IGPEB	Graecum
7	Akmarvarid	Uzbekistan	IGPEB	Graecum
8	Dordoy 16	Kyrgyz Republic	IGPEB	Graecum
9	Dank	Kyrgyz Republic	IGPEB	Ferrugineum
10	Bayandy	Kazakhstan	IGPEB	Lutescens
11	Shapagat	Kazakhstan	IGPEB	Spring Lutescens
12	Raminal	Kazakhstan	IGPEB	Lutescens
13	Maira	Kazakhstan	IGPEB	Lutescens
14	Sapali	Kazakhstan	IGPEB	Erytrospermum
15	Krasnovodopadskaya 210’	Kazakhstan	IGPEB	Erytrospermum

* Institute of Genetics and Plant Experimental Biology

In 2021, the research worked on two different environmental conditions (E = environment): a) optimal water conditions (irrigated field – E1) and b) water-deficit conditions (non-irrigated conditions – E2). In 2022, the research comprised different combinations of wheat seed and water regimes, i.e., E3 (seeds obtained under optimal water conditions and also grown under irrigated conditions), E4 (seeds obtained under water-deficit conditions and grown under optimal water conditions), E5 (seeds obtained under optimal conditions and grown under water-deficit settings), and E6 (seeds obtained under water-deficit conditions and also raised under the same conditions) (Figure 1).

Assessment of climate variability

The hydrothermal humidity coefficient (HTC), described by Selyaninov (1930) as a characteristic of the level of moisture available in the grown area, used the following formula for its calculation:

$$HTC = R \times 10/\Sigma t$$

Where:
R is the sum of precipitation in millimeters (mm) for a period with a temperature above +10 °C, and Σt is the sum of temperatures for this period in °C (Zinkovsky and Zinkovskaya, 2018; Zinkovskaya *et al.,* 2019). However,

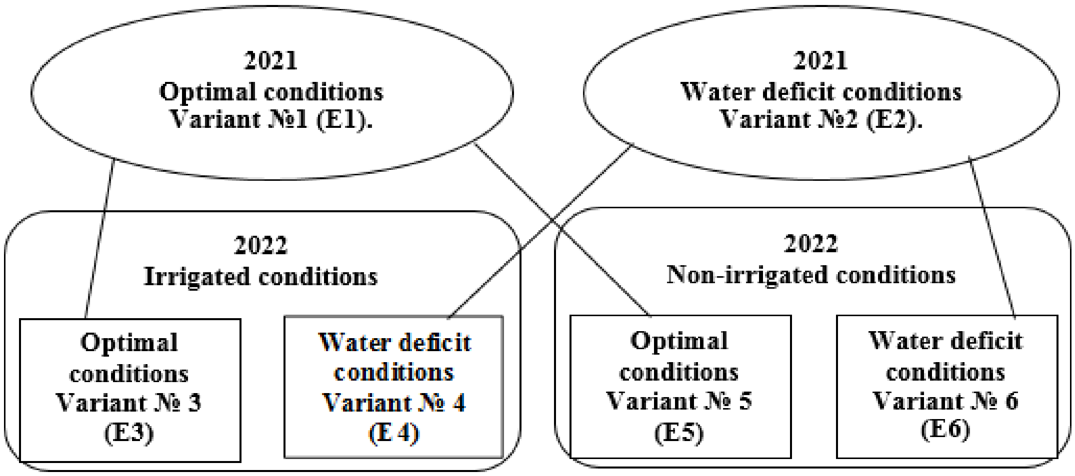

Figure 1. Scheme of wheat experiments during 2021–2022.

according to Evarte-Bundere and Evarts-Bunders (2012), the HTC ranges were as follows:

HTC from 1.0 to 2.0 – humidity is sufficient
- HTC > 2.0 – profusely humid
- HTC < 1.0 – insufficient humidity
- HTC from 1.0 to 0.7 – dry
- HTC from 0.7 to 0.4 – very dry

Chlorophyll content

Assessing the value of SPAD-chlorophyll had a portable chlorophyll meter, SPAD-502 (Minolta Co., Ltd., Osaka, Japan). For this purpose, 10 randomly selected plants from each plot were samples to measure the chlorophyll content. Acquiring readings came from a flag leaf at the flowering stage from three different points (the bottom, middle, and tip of the leaf), then averaged to obtain the final SPAD-chlorophyll value.

Statistical analysis

Genotype productivity data compilation used the computer software Statistical 6.0 and Microsoft Excel. Correlation analysis ensued with the analysis of variance (ANOVA) method.

RESULTS

Climate variability and hydrothermal coefficient

By calculating the hydrothermal coefficient for 2021–2022, in the first 10 days of April 2021, the total precipitation was 23.0 mm and the HTC = 2.93, followed by a severe drought, which resulted in reduced rains and very high temperatures, giving a HTC value of 0.62.

In March 2022, precipitation was abundant, i.e., 13.8 mm in the first 10 days (HTC = 5.75) and 80.8 mm in the third week (HTC = 14.28), providing moderate humidity, while in April 2022, there was a water shortage. In the first 10 days, the fourth week of May, and the third week of June 2022, the precipitation was 21.0, 20.1, and 21.3 mm, respectively, and in combination with high temperatures, a moisture deficit condition was evident (Figure 2). One must note that this soil moisture level was sufficient for the full formation of grains during the period of earing.

Climate variability for the two crop seasons made it possible to determine the genotype's resistance to various external factors. Determining the degree of tolerance to water deficiency due to lack of moisture (2021)

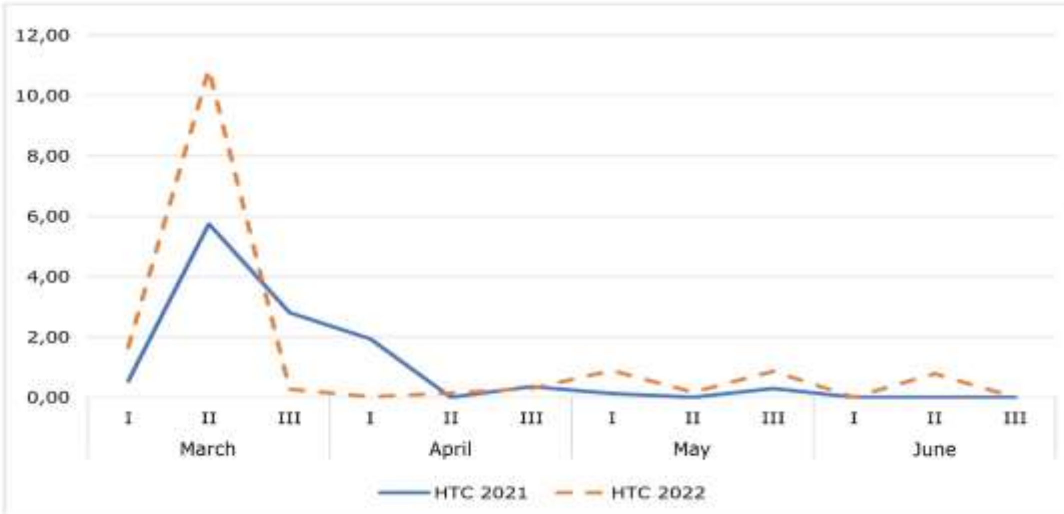

Figure 2. The hydrothermal humidity coefficient (HTC) during the vegetation period of wheat genotypes in 2021–2022.

provided a better opportunity to verify resistance to diseases, tolerance to lodging caused by high humidity (2022), and the ability to maximize grain yield.

Leaf chlorophyll content measurement

The commencement of spring boosted the intensive growth and development of wheat plants, aiding in the assessment of various wheat genotypes for chlorophyll content. From the heading phase to the end of the plant growth and life cycle, gauging the productivity of diverse genotypes can be easy, as well as, the influence of external environmental factors on grain yield (Platovsky *et al*., 2021). During 2021, under optimal conditions (E1), in 15 wheat cultivars, the average chlorophyll content was 42.6 ± 0.9; under water deficiency (E2), the said value was 41.8 ± 0.8 (Table 2). In 2022, under high humidity conditions of E3 and E4, the chlorophyll content was 54 ± 0.8, and under environmental conditions E5 and E6, the average value for the said trait was 53.6 ± 0.4 and 53.4 ± 0.6, respectively.

In the studied cultivars during the dry crop season, the chlorophyll content was about 10 units less than in a crop season with high humidity in an early stem elongation phase of wheat. Compared with other wheat cultivars, the cultivar 'Pakhlavon' revealed less chlorophyll content; however, this indicator changed little in the two distinct variants of the experiment, indicating its better resistance to varied climatic conditions. The same results were evident in the wheat cultivars 'Andijan 4,' 'Maira,' 'Grom,' and 'Dank' (awned). However, wheat cultivars 'Ezoz,' 'Bayandy,' 'Krasnovodopadskaya,' and 'Shapagat' appeared to be relatively more sensitive to climate variations. In the cultivars 'Raminal,' 'Sapali,' 'Vassa,' and 'Dordoy 16,' the chlorophyll amount was relatively higher under dry conditions than the optimal irrigation.

The highest chlorophyll content under all the environmental conditions emerged in the wheat cultivars of the Kazakh selection, 'Krasnovodopadskaya 210' and 'Bayandy.' Said cultivars, as expected under optimal conditions, the chlorophyll content was higher than under provisional drought conditions (Table 2). Various cultivars of wheat also differed in the chlorophyll content, with the highest chlorophyll content recorded in the cultivar 'Krasnovodopadskaya 210' (49.4), whereas the minimum in cultivar 'Pakhlavon' (36.7). However, the interaction effects of the wheat genotypes with varied levels of drought were nonsignificant.

Table 2. Effect of climate change on the chlorophyll content in wheat cultivars during the flowering phase.

No.	Cultivars	2021		2022				Means	CV%
		E1	E2	E3	E4	E5	E6		
1	Akmarvarid	41.9	39.4	51.5	52.7	54.4	54.6	49.1±2.7	13.6
2	Andijan 4	42.4	42.3	55.9	53.8	54.8	55.3	50.8±2.7	12.9
3	Durdona	43.6	41.7	56.6	58.1	54.5	52.8	51.2±2.8	13.5
4	Ezoz	44.3	42.5	55.4	56.5	52.8	48.4	50.0±2.4	11.7
5	Pakhlavon	36.7	36.6	47.8	46.5	51.4	48.8	44.6±2.6	14.3
6	Bayandy	48.4	45.4	56.3	52.5	57.1	55.2	52.5±1.9	8.9
7	Raminal	41.4	42.7	53.5	54.1	53.0	56.8	50.2±2.7	13.0
8	Krasnovodopadskaya 210	49.4	46.2	59.8	58.1	53.8	56.8	54.0±2.2	9.8
9	Sapali	38.2	40.1	53.7	54.5	53.6	52.9	48.8±3.1	15.5
10	Shapagat	41.2	37.8	55.9	50.3	53.3	57.6	49.4±3.3	16.4
11	Maira	39.5	39.0	52.1	53.7	51.3	47.5	47.2±2.7	13.8
12	Grom	45.8	45.0	49.9	54.3	52.4	50.9	49.7±1.5	7.4
13	Vassa	44.2	45.7	52.5	54.8	52.8	56.0	51.0±2.0	9.6
14	Dank (ostistaya)	42.8	42.6	53.9	51.8	53.0	52.1	49.4±2.1	10.6
15	Dordoy 16	38.8	40.5	56.3	57.9	55.8	54.6	50.6±3.5	17.0
	Means	42.6	41.8	54.1	54.0	53.6	53.4		

Table 3. Two-factor analysis of the influence of environmental conditions on wheat cultivars' chlorophyll content and productivity.

Variables	Climate	Genotype	Other factors
Chlorophyll (SPAD)	72.0	12.7	15.3
Grain yield (g m^2)	11.5	42.6	45.9

Analysis of grain yield

All 15 soft wheat cultivars selected from the various regions of Central Asia showed higher grain yield in terms of genotype potential under the climatic conditions of Uzbekistan (Table 3). The results also indicated the full maturation periods of the studied cultivars under different experimental variants. In 2021, crops from irrigated conditions were distinct as optimal (E1), and water deficit (without irrigation) on yield and chlorophyll content indicated as a stress condition (E2) (Figure 3). The crop season 2022 is descriptive of abundant rains, which led to soil waterlogging. Herein, the irrigated conditions experienced high humidity (E3 and E4), while non-irrigated conditions sustained relatively moderate humidity (E5 and E6).

Under optimal conditions (E1), the wheat productivity was higher than the same in other options. However, the lowest productivity was apparent under water deficit conditions. For chlorophyll content, a higher value occurred under environmental conditions E3 and E4, whereas a low value for chlorophyll content was traceable under the water deficiency conditions (E2). Two-factor analysis of variance revealed that the chlorophyll content had external factors strongly affecting it, and the specificity of the cultivars was only 12.7%. Other factors, such as, the volume and pubescence of the leaf and the soil conditions, had an impact of 15.3%. The influence of the environment on the grain yield, on the contrary, was relatively low, and the grain yield was mainly dependent on the varietal agrotechnology and the genotype itself.

Noticeably, various genotypes responded differently to the growing conditions. In the first year (2021), when the experiment included only two irrigation regimes, i.e., irrigated and non-irrigated conditions, naturally, the grain yield was higher under irrigated conditions than in the non-irrigated variant in almost all the wheat

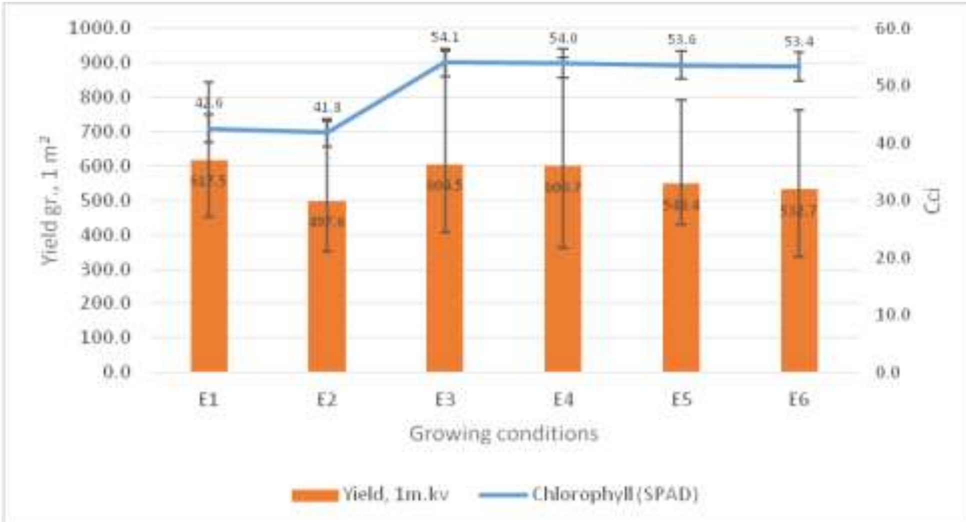

Figure 3. Dependence of the wheat chlorophyll content and productivity on environmental variations.

genotypes. The highest grain yield under both irrigated conditions was visible in the cultivar 'Raminal' (belonging to Kazakh selection); however, the low harvest under irrigation conditions was notable in the cultivars 'Akmarvarid' and 'Maira' and in cultivar 'Vassa' without irrigation.

In 2022, during the second year, when humidity was high during grain accumulation, the cultivar 'Akmarvarid' showed the highest grain yield. In this cultivar, the higher yield was distinct even under the E6 condition (when the seeds obtained under water-deficit conditions in 2021 were grown again under water shortage in 2022). However, the average harvest was relatively higher than in other genotypes in all the experiment variants. The variety 'Raminal' gave a higher grain yield in almost all variants and a relatively low output under E5 conditions.

Wheat cultivars 'Grom' and 'Vassa,' considered high-yielding in the Republic, have large-area cultivation in Uzbekistan. However, in these experiments, the genotypes showed a relatively low grain yield under all the irrigation regimes (Table 4). It is necessary to enhance the grain yield and selection of cultivars due to spike weight and the number of grains per spike (Qulmamatova *et al.,* 2022). Therefore, genetic diversity can benefit various breeding programs to develop high-yielding genotypes and hybrids adapted to water-deficient areas (Adilova *et al.,* 2020).

Correlation analysis of the traits

The correlation analysis between the chlorophyll content and wheat growing and environmental conditions ensued. There was a weak negative relationship between the SPAD index and the cultivar's cultivation conditions with water deficit and high humidity (E2 [r = -0.29] and E3 [r = -0.34], respectively). However, on average, the said association was positive in other environmental conditions.

A weak relationship was discernible between the chlorophyll content and the total grain yield. Between these two traits, in genotypes grown under E3 and E5 variants (the seeds obtained from plants grown under optimal water conditions), as well as, between E5 and E6, an average positive relationship existed with correlation coefficient values of r = 0.48 and r = 0.33, respectively. Data analysis further showed that the correlation coefficient between productivity and growing conditions, on average, was moderately positive for all environments over the years of research (Table 5). It indicates a relatively high degree of conjugation of environmental conditions with the photosynthetic pigments found in winter wheat plants.

Table 4. Impact of climate change on the grain yield (g/m^2) of various wheat genotypes.

No.	Cultivars	2021		2022				Means	C.V.%
		E1	E2	E3	E4	E5	E6		
1	Akmarvarid	496.0	408.0	935.3	672.4	555.6	760.5	638.0±78.4	30.1
2	Andijan 4	686.0	626.5	742.6	726.6	495.4	560.0	639.5±39.8	15.3
3	Durdona	595.5	369.5	514.7	461.9	430.5	365.3	456.2±36.2	19.4
4	E'zoz	555.0	378.0	406.4	363.3	481.4	490.0	445.7±30.6	16.8
5	Pakhlavon	595.0	450.5	514.7	490.8	547.1	547.3	524.2±20.6	9.6
6	Bayandy	609.0	478.5	770.1	520.1	607.8	562.8	591.4±41.3	17.1
7	Raminal	845.5	731.5	710.2	915.5	529.6	763.5	749.3±53.9	17.6
8	Krasnovodopadskaya 210	654.0	579.5	472.1	608.4	557.6	756.2	604.6±39.1	15.8
9	Sapali	796.5	481.0	523.7	785.4	792.5	402.6	630.3±73.8	28.7
10	Shapagat	613.0	579.0	549.2	582.9	555.2	477.2	559.4±18.9	8.3
11	Maira	453.0	434.0	479.5	540.7	464.3	515.5	481.2±16.4	8.3
12	Grom	598.0	527.0	628.4	512.4	557.2	470.2	548.9±23.7	10.6
13	Vassa	566.0	353.5	492.7	389.8	491.2	336.4	438.3±37.4	20.9
14	Dank (awned)	626.0	503.0	731.9	720.0	724.2	441.9	624.5±51.2	20.1
15	Dordoy 16	574.5	564.0	595.7	720.0	436.4	540.4	571.8±37.4	16.0

Table 5. Correlation coefficient between wheat chlorophyll content and productivity under varied environmental conditions.

Variables		Chlorophyll						Productivity					
		E1	*E2*	*E3*	*E4*	*E5*	*E6*	*E1*	*E2*	*E3*	*E4*	*E5*	*E6*
Chlorophyll	*E1*	1											
	E2	-0.29	1										
	E3	-0.34	-0.07	1									
	E4	0.41	0.35	0.05	1								
	E5	0.36	0.39	0.01	0.34	1							
	E6	0.32	0.11	-0.04	0.17	0.55	1						
Productivity	*E1*	-0.13	-0.05	-0.06	0.28	0.08	0,16	1					
	E2	-0.32	0.08	-0.12	0.1	-0.07	-0.11	0.66	1				
	E3	-0.04	0.05	-0.17	-0.31	0.48	0.13	0.08	0.28	1			
	E4	-0.16	-0.16	-0.2	-0.06	0.08	-0.13	0.66	0.76	0.51	1		
	E5	-0.27	0.02	0	-0.1	0.14	-0.18	0.46	0.1	0.23	0.39	1	
	E6	0.15	-0.13	0.03	-0.07	0.33	0.15	0.16	0.53	0.46	0.47	-0.08	1

DISCUSSION

In leaves of wheat genotype, variations in the chlorophyll content play a vital role in manifesting drought resistance. In drought-resistant and stable-bread wheat cultivars under unfavorable conditions, the chlorophyll content varied slightly, while in unstable cultivars, a sharp decrease was evident (Alaei, 2011). In the presented studies, such a sudden variation was not distinct among the wheat cultivars for chlorophyll content because all the selected genotypes were pre-selected for resistance to water deficit conditions.

The studies of the bread wheat cultivars in Pakistan obtained the same results, with higher chlorophyll content observed under well-irrigated conditions but decreased significantly under drought conditions ranging from 50 to 55 (Wasaya *et al.,* 2021). Severe drought conditions inhibit plant photosynthesis by affecting chlorophyll components, damaging the photosynthetic apparatus, and causing changes in chlorophyll content (Iturbe-Ormaetxe *et al.,* 1998). Ommen *et al.* (1999) also reported reduced chlorophyll content in the spring wheat leaves under drought conditions. Research also noted that the reduction in chlorophyll content under water deficit conditions was mainly due to the damage to chloroplasts by reactive oxygen species in crop plants (Smirnoff and Wheeler, 2000; Turaev *et al*., 2023).

However, Khayatnezhad *et al.* (2011) reported that when exposing resistant wheat genotypes to drought, green chlorophyll tissues increased in their leaves. An influential factor in drought stress resistance is that genotypes with a high chlorophyll content in leaves were mostly resistant to stress conditions. The same was well-stated in the work of Abilfazova (2016), in which low oxidative and high photosynthetic activity of leaves of resistant peach cultivars and clones were evident under various stress factors, i.e., high soil moisture and low air temperature during the spring flowering period.

In the work of Pryadkina *et al.* (2014) on spring wheat genotypes, it was prominent under optimal weather conditions that mostly, crop amount correlated with the chlorophyll photosynthetic potential (ChlPP), which characterizes the total chlorophyll content in the aboveground parts of wheat plants per unit of planted area for the growing season. However, global climate change can lead to violations of the relationship between photosynthetic parameters and grain yield. The prevailing studies also revealed that high temperatures decreased the chlorophyll content in the leaves, the size of the assimilation surface of crops, the duration of functioning, and the grain yield.

In this regard, one must note that the pigment complex of a plant organism is one of the systems highly volatile to variations in environmental conditions. Therefore, chlorophyll pigments respond to minimum variations in the environment, such as, high temperature and insufficient water supply, causing the destruction of chloroplasts and, thereby, violating the synthesis of chlorophyll *a* and *b*, changing the bonds' strength in the chlorophyll-protein-lipid complex of the plastid (Abilfazova, 2016).

CONCLUSIONS

Based on the findings, a discovery verified that the wheat genotypes under study react to climate change in various ways. Under optimal irrigated conditions (E1), the highest grain yield was prominent in the cultivar 'Raminal' of the Kazakh selection in all the environmental conditions. The cultivar 'Vassa' of Russian breeding and cultivar 'E'zoz' from the CIMMYT collection occurred sensitive to water-deficit settings. The cultivars, 'Akmarvarid' and 'Andijan-4' of the Uzbek selection and 'Bayandy' and 'Raminal' of the Kazakh selection, proved tolerant to high humidity (E3). The chlorophyll content attained more influence from the environmental conditions than from wheat genotypes. Among the 15 studied wheat genotypes, the cultivar 'Pakhlavon' had a relatively low SPAD, and the cultivar 'Bayandy' had a relatively high SPAD value; but, for other cultivars, the trait values were moderate. Significant differences were also apparent among the wheat genotypes grown in different raising conditions. In the first year (2021), when the weather was relatively dry, the average SPAD value under irrigated conditions was 42.6, while under relative water-deficit conditions, the value was 41.8. For the second year (2022), in wet weather, the chlorophyll content ranged from 53.4 to 54.1 under four growing options; however, it differed by almost 10 units from the first-year results.

ACKNOWLEDGMENTS

The presented study proceeded within the framework of the A-FA-104 project, with financial support from the Agency of Innovative Development under the Ministry of Higher Education, Science and Innovations of the Republic of Uzbekistan.

REFERENCES

Abilfazova YS (2016). The pigment composition of peach leaves in the conditions of the Black Sea coast of the Krasnodar Territory. *Mat scientific. Conf.* Factors of resistance of plants and microorganisms in extreme natural conditions and industrial environment, Irkutsk, pp. 40-41.

Adilova SS, Qulmamatova DE, Baboev SK, Bozorov TA, Morgunov AI (2020). Multivariate cluster and principle component analyses of selected yield traits in Uzbek bread wheat cultivars. *Am. J. Plant Sci*. 11: 903-912. https://doi.org/10.4236/ajps.2020.116066.

Adylova AT, Norbekov JK, Khurshut EE, Nikitina EV, Kushanov FN (2018). SSR analysis of the genomic DNA of perspective Uzbek hexaploid winter wheat varieties. *Vavilov J. Genet. Breed.* 22(6): 634-639.

Alaei Y (2011). The effect of amino acids on leaf chlorophyll content in bread wheat genotypes under drought stress conditions. *Middle-East J. Sci. Res*. 10(1): 99-101.

Baboyeva SS, Bohodirov US, Usmonov RM (2021). Phenotyping of common wheat varieties by the number of chlorophylls in drought conditions. *Acad. Res. Edu. Sci*. 2(11): 14-23.

Baboyeva SS, Usmanov RM, Baboev SK (2022). Environmental impact on the index of productivity of winter wheat. *Edu. Res. in Uni. Sci.* 1(5): 311-323.

Blackmer TM, Schepers JS (1995). Use of a chlorophyll meter to monitor nitrogen status and schedule fertigation for corn. *J. Prod. Agric*. 8(1): 56-60.

Boggs JL, Tsegaye TD, Coleman TL, Reddy KC, Fahsi A (2003). Relationship between hyperspectral reflectance, soil nitrate-nitrogen, cotton leaf chlorophyll, and cotton yield: A step toward precision agriculture. *J. Sustain. Agric.* 22(3): 5-16.

Doroshkov AV, Afonnikov DA, Dobrovolskaya OB, Pshenichnikova TA (2016). Interactions between leaf pubescence genes in bread wheat as assessed by high throughput phenotyping. *Euphytica* 207: 491-500.

Earl HJ, Tollenaar M (1997). Maize leaf absorptance of photosynthetically active radiation and its estimation using a chlorophyll meter. *Crop Sci*. 37(2): 436-440.

Evarte-Bundere G, Evarts-Bunders P (2012). Using of the hydrothermal coefficient (HTC) for interpretation of distribution of non-native tree species in Latvia on example of cultivated species of genus *Tilia*. *Acta Biol. Univ. Daugavp.* 12(2): 135-148.

Fox RH, Piekielek WP, Macneal KE (2001). Comparison of late-season diagnostic tests for predicting nitrogen status of corn. *Agron. J.* 93(3): 590-597.

Isadzhanov AA (2020). Digital agriculture and climate change. *Young Scientists Forum* 6(46): 265-269.

Iturbe-Ormaetxe I, Escuredo PR, Arrese-Igor C, Becana M (1998). Oxidative damage in pea plants exposed to water deficit or paraquat. *Plant Physiol*. 116(1): 173-181.

Khayatnezhad M, Zaeifizadeh M, Gholamin R (2011). Effect of end-season drought stress on chlorophyll fluorescence and content of antioxidant enzyme superoxide dismutase enzyme (SOD) in susceptible and tolerant genotypes of durum wheat. *Afr. J. Agric. Res.* 6(30): 6397-6406.

Kushanov FN, Komilov DJ, Turaev OS, Ernazarova DK, Amanboyeva RS, Gapparov BM, Yu JZ (2022). Genetic analysis of mutagenesis that induces the photoperiod insensitivity of wild cotton *Gossypium hirsutum* Subsp. *purpurascens*. *Plants* 11(22): 3012. https://doi.org/10.3390/plants11223012.

Maiti D, Das DK, Karak T, Banerjee M (2004). Management of nitrogen through the use of leaf color chart (LCC) and soil plant analysis development (SPAD) or chlorophyll meter in rice under irrigated ecosystem. *Scien. World J.* 13(4): 838-846.

Ommen OE, Donnelly A, Vanhoutvin S, Van Oijen M, Manderscheid R (1999). Chlorophyll content of spring wheat flag leaves grown under elevated CO2 concentrations and other environmental stresses within the 'ESPACE-wheat' project. *Eur. J. Agron*. 10(3-4): 197-203.

Orlovsky NS, Zonn IS, Kostyanoy AG, Zhiltsov SS (2019). Climate change and water resources in Central Asia. *Bull. Diplomatic Acad. Ministry of Foreign Affairs, Russia. Russia and the world* 1: 56-78.

Parvizi Y, Ronaghi A, Maftoun M, Karimian NA (2004). Growth, nutrient status, and chlorophyll meter readings in wheat as affected by nitrogen and manganese. *Commun. Soil Sci. Plant Anal.* 35(9-10): 1387-1399.

Platovsky N, Zdioruk N, Ralia T, Gore A (2021). Effect of BAS Reglalg on the rate of maturation of different genotypes of winter wheat (*Triticum aestivum* L.). Proceedings of the III International Scientific

Conference: In Trends in the development of agrophysics: From current problems of agriculture and crop production to future technologies, pp. 405-409.

Pradhan GP, Prasad PVV, Fritz AK, Kirkham MB, Gill BS (2012). Effects of drought and high temperature stress on synthetic hexaploid wheat. *Funct. Plant Biol.* 39(3): 190-198. doi: 10.1071/FP11245.

Pryadkina GA, Stasik OO, Mikhalskaya LN, Shvartau VV (2014). Relationship between chlorophyll photosynthetic potential and yield of winter wheat (*Triticum aestivum* L.) at elevated temperatures. *Agric. Biol.* 5: 88-95.

Qulmamatova DE, Baboev SK, Buronov AK (2022). Genetic variability and inheritance pattern of yield components through diallel analysis in spring wheat. *SABRAO J. Breed. Genet.* 54(1): 21-29. http://doi.org/10.54910/sabrao2022.54.1.3.

Ramesh K, Chandrasekaran B, Balasubramanian TN, Bangarusamy U, Sivasamy R, Sankaran N (2002). Chlorophyll dynamics in rice (*Oryza sativa*) before and after flowering based on SPAD (chlorophyll) meter monitoring and its relation with grain yield. *J. Agron. Crop Sci.* 188(2): 102-105.

Selyaninov GT (1930). Methods of agricultural climatology (in Russian). *Agric Meteorol*. 22.

Smirnoff N, Wheeler GL (2000). Ascorbic acid in plants: Biosynthesis and function. *Crit. Rev. in Plant Sci.* 19(4): 267-290.

Spaner D, Todd AG, Navabi A, McKenzie DB, Goonewardene LA (2005). Can leaf chlorophyll measures at differing growth stages be used as an indicator of winter wheat and spring barley nitrogen requirements in eastern Canada? *J. Agron. Crop Sci.* 191(5): 393-399.

Turaev OS, Baboev SK, Ziyaev ZM, Norbekov JK, Erjigitov DSh, Bakhadirov USh, Tursunmurodova BT, Dolimov AA, Turakulov KhS, Ernazarova DK, Kushanov FN (2023). Present status and future perspectives of wheat (*Triticum aestivum* L.) research in Uzbekistan. *SABRAO J. Breed. Genet*. 55(5): 1463-1475. http://doi.org/10.54910/sabrao2023.55.5.2.

Wasaya A, Manzoor S, Yasir TA, Sarwar N, Mubeen K, Ismail IA, Raza A, Rehma A, Hossain A, EL Sabagh A (2021). Evaluation of fourteen bread wheat (*Triticum aestivum* L.) genotypes by observing gas exchange parameters, relative water and chlorophyll content, and yield attributes under drought stress. *Sustainability* 13(9): 4799.

Zinkovskaya T, Zinkovsky V, Sorokina V, Shakhparonyan L (2019). The use of environmentally secure means of biological reclamation in order to prevent soil degradation processes. *Bull. Sci. Pract.* 5(3): 144-149.

Zinkovsky VN, Zinkovskaya TS (2018). Considering atmospheric precipitations at agromeliorative calculations. *Int. Res. J.* 5(71): 130-135. doi: https://doi.org/10.23670/IRJ.2018.71.019.