RESEARCH ARTICLE

SABRAO Journal of Breeding and Genetics
54 (5) 976-992, 2022
http://doi.org/10.54910/sabrao2022.54.5.2
http://sabraojournal.org/
pISSN 1029-7073; eISSN 2224-8978

GENETIC VARIABILITY AND INHERITANCE OF PHYSIOLOGICAL AND YIELD TRAITS IN UPLAND COTTON UNDER DIVERSE WATER REGIMES

H. MATNIYAZOVA[1,2], S. NABIEV[1], A. AZIMOV[1], and J. SHAVKIEV[1,2,*]

[1]Institute of Plant Genetics and Experimental Biology, Academy of Sciences, Tashkent, Uzbekistan
[2]Chirchik State Pedagogical Institute of Tashkent Region, Chirchik City, Uzbekistan
Corresponding author's email: jaloliddinshavkiev1992@gmail.com
Email addresses of co-authors: matniyazova@mail.ru; m.saydigani@mail.ru; azimov.abdulahat@bk.ru

SUMMARY

Water scarcity during the flowering and ripening stages disrupts physiological processes in crop plants. The recent study on cotton genotypes and their F_1 hybrids under two different water regimes (non-stress and stressed conditions) took place in 2018–2020 at the Institute of Genetics and Experimental Biology, Academy of Sciences, Tashkent, Uzbekistan. In optimum and controlled water regimes, the cotton genotypes received irrigation four times, using 4800-5000 m^3/ha water. However, under stress conditions, the genotypes received only two irrigations, using 2800-3000 m^3/ha water. Comparing the optimum water regime with the water stress conditions, chlorophyll 'b' in plant leaves decreased by 3.0% to 46.7% and 1.1% to 26.2% in the parental cultivars and their F_1 hybrids, respectively. With water deficit conditions, the carotenoid content increased from 8.5% to 39.1% and 2.1% to 44.2% in plant leaves of parental cultivars and their F_1 hybrids, respectively, compared with the optimal water condition, which indicates how cotton genotypes protect themselves from water scarcity by varying magnitudes of carotenoids in plant leaves. The use of decreased levels of chlorophyll 'a' and 'b' and increased levels of carotenoids aided the inhibition of oxidants during photooxidation under drought conditions. The F_1 hybrids viz., Listopad × Farovon (62.2±0.9 g.), F_1 Kupaysin x Elastik (55.8±1.2 g.), F_1 Listopad × Kupaysin (55.7±0.2 g.) produced higher seed cotton yield, which might be due to their resistance to drought conditions, as well as heterosis. These promising populations proved suitable for developing drought-tolerant cotton genotypes in future breeding programs.

Keywords: *Gossypium hirsutum* L., water regimes, drought conditions, physiological traits, chlorophyll, carotenoids, yield-related parameters

Key findings: The F_1 promising populations, i.e., Listopad × Farovon, Kupaysin x Elastik, and Listopad × Kopaysin, showed resistance to drought conditions and gave higher heterosis and productivity under water deficit conditions.

Communicating Editor: Prof. Naqib Ullah Khan

Manuscript received: September 13, 2022; Accepted: November 14, 2022.

INTRODUCTION

Drought is one of the recognized environmental stresses limiting crop yields in most parts of the world, especially in warm and dry areas (Porudad and Beg, 2003). Climate change also increases drought in most parts of the world (Jones and Van-Vliet, 2018). Thus, a

To cite this manuscript: Matniyazova H, Nabiev S, Azimov A, Shavkiev J (2022). Genetic variability and inheritance of physiological and yield traits in upland cotton under diverse water regimes. *SABRAO J. Breed. Genet.* 54(5): 976-992. http://doi.org/10.54910/sabrao2022.54.5.2.

great need for water resources for irrigation persists in meeting the demand for crops in the region. The irrigation water requirements come from the aquifer, the principal groundwater source (Bhattarai *et al.,* 2020). In most arid regions of the world, plants experience water stress conditions, and damaged plant cells due to water deficiency affect the physiological processes, leaf growth, photosynthesis, leaf tip closure, and changes in metabolism, leading to the drying and death of plants (Rahmani, 2006). Leila (2007) has also pointed out that environmental stresses, including drought, often affect most of the critical stages of plant growth.

Under the influence of abiotic stress factors, the reduction in valuable economic traits in cotton cultivars belonging to the genus *G. hirsutum* L. revealed varying degrees (Rejapova *et al.,* 2020). Soil moisture stress induces various morpho-physiological and biochemical adaptations in plants, which subsequently inhibit plant growth, reduce photosynthesis, impair stomatal permeability and transpiration, reduce chlorophyll content, and lead to changes in proteomics (Lu and Zhang, 1999; Reddy *et al*., 2004; Wijewardana *et al.,* 2018, 2019).

Drought tolerance is the ability of a species and cultivar to grow and develop under drought-stress conditions. Physiological and morphological characteristics that affect fertility during a long, dry period depend on many factors. Not only is this due to the drought that occurs during the life cycle of plants and the water permeability of the soil in the root zone but also to the biological properties of the crop plants (Mohsenzadeh *et al.,* 2006). Cuticular resistance increases significantly as a result of water scarcity. In some crops, in response to water scarcity, an active movement showed in the leaves parallel with sunlight (Rahmani, 2006.). Kresovic *et al.* (2017) studied the effects of irrigation regimes on soybean seeds and reported that irrigation had a relevant impact on the soybean yield and protein content.

Drought stress affects an increase in leaf levels to reduce water loss in some plants (Leila, 2007). Saving water and ensuring efficient water absorption describe as one manifestation of drought tolerance in plants. Among other factors, the roots must have a high ability to absorb water (Zareian, 2004). Plants begin to shed their old leaves to keep the amount of water in their leaves at a safe level. Such arrangement of leaves occurs to improve resilience to long-term changes in the environment and water scarcity (Maleki *et al.,* 2013). Gas exchange regulates water loss (transpiration) and CO_2 uptake through the stomatal pores. Transpiration and CO_2 uptake occur in plants, which are crucial physiological processes, where transpiration is an inevitable result of photosynthesis (Lambers and Oliveira, 2019).

In general, the rate of photosynthesis decreases with increasing water deficit. However, stomatal permeability is more sensitive to water deficiency than the photosynthesis rate. As a result, the internal efficiency of water use increases under moderate water pressure conditions (Pazzagli *et al.,* 2016). With water pressure conditions, the rate of leaf expansion decreases, reducing the rate of leaf growth, resulting in a decline in the specific photosynthesis area for each plant, as well as, the photosynthesis rate per unit of leaf area, leading to a decrease in total photosynthesis for each plant (Parkash and Singh, 2020a, b). A decrease in total photosynthesis for each plant adversely affects plant growth, leading to a decline in yield under water stress conditions (Singh *et al.,* 2019). Plants can survive water stress up to a certain limit without causing a significant decrease in plant growth and productivity, however, drought stress resistance varies among the crops (Mohawesh, 2016; Wakchaure *et al.,* 2018; Singh *et al.,* 2019).

Stomatal permeability and leaf water potential remained stable in the cultivar Da-Vinci, becoming unstable in the cultivars Missiya and Super Nektar in melon (*Cucumis melo* L.) under water stress conditions (Sharma *et al.*, 2019). It suggests that crop cultivars may vary in their resistance and susceptibility to water stress. Water deficit conditions close plant stomata under drought, which affects photosynthetic activity (Parkash and Singh, 2020a). Stomatal permeability is inversely related to stomatal resistance, which determines the degree of resistance to gas exchange between the leaf and the surrounding air due to stomatal closure (Parkash and Singh, 2020b).

Water deficiency degrades photosynthetic pigments, reducing the amount of chlorophyll and disrupting the photosynthesis process. A significant decrease in chlorophyll content and synthesis might create dehydration, indirectly increasing chlorophyll catabolism. Decreases in chlorophyll content due to water deficiencies have also been observed in olive and wheat crops (Loggini, 1999). Photosynthesis is a global natural source of renewable energy on earth, ensuring the full functioning of all organs of a green plant. Therefore, it serves as a key factor in the production process of crops. Photosynthesis forms 95% of plant organic matter (Medvedev, 2004). The decrease in photosynthesis relates to the main components of the chloroplast, which directly limit the photosynthetic potential of the plant (Muhammad *et al.,* 2014.).

The low concentration of photosynthetic pigments and the decrease in photosynthetic potential inhibit plant productivity. The amount of chlorophyll in the leaf is one of the most significant indicators from a physiological point of view. A study reported the loss of chlorophyll content in a water-deficient environment occurs with the destruction of masked cells in plants (Anjum *et al,* 2011). Carotenoids, one of the main components of chloroplasts in plants, protect plants from photooxidation under stress (Ahmad *et al.,* 2013). With all the above, the latest study aimed to learn the physiological and yield traits in upland cotton parental genotypes and their F_1 hybrids under water deficit conditions.

MATERIALS AND METHODS

Experimental site and genetic material

The recent research proceeded during 2018-2020 at the Institute of Genetics and Experimental Biology, Academy of Sciences of the Republic of Uzbekistan, located in the District Zangiota, Tashkent, Uzbekistan (with an altitude of 398 masl). The climate exhibited sharp fluctuations, with high temperatures in summer (June, July, and August) and a sharp drop in air temperature in winter (December and January). Sunny days prevailed for 175-185 days and non-cold days for 200-210 days. It rains in the fall, winter, and spring, with the air dry in the summer. The soils of the experimental field were low in humus, typically gray, and moderately sandy according to the granulometric composition. The terrain is slightly sloping, not saline, and naturally damaged by whitish (verticillus) silt. The bulk density of the soil measured 1.32–1.33 g/cm^3, with a limited field moisture capacity (LFMC) of 22%. Groundwaters go deep (8 m and more) (Shavkiev *et al*., 2020, 2021).

The study took place on cotton genotypes and their F_1 hybrids under two water regimes (non-stress and stressed conditions). In optimum and controlled water regimes, the cotton genotypes received irrigation four times (scheme 1:2:1) during the vegetative and flowering stages, using 4800-5000 m^3/ha water. However, under stress conditions, only two irrigations (scheme 1:1:0) were applied to the genotypes, with the total volume of water used for irrigation at 2800-3000 m^3/ha. In the stressed environment, the cotton genotypes were irrigated once during the seedling and once at the flowering stage, artificially creating water scarcity (modeled drought). A group of parental cotton cultivars belonging to the species *Gossypium hirsutum* L. and their F_1 hybrids underwent the study.

Data recorded

The experiment determined the amounts of chlorophyll 'a,' 'b,' and carotenoids in plant leaves. In this case, samples came from three to four leaves of the cotton plant, starting the count from the point of growth in field conditions. Placing each leaf of 50 mg in a test tube followed. Each leaf sample underwent homogenization in 5 ml of 95% ethyl alcohol solution (Sumanta *et al.*, 2014). The homogenate centrifugation took a speed of 5000 for 12 min. An Agilent Cary 60 UV-Vis spectrophotometer at 664, 649, and 470 nm determined the amounts of chlorophyll 'a,' 'b,' and carotenoids in the resulting extract. Based on this indicator, the amount of chlorophyll 'a,' 'b,' and carotenoids in cotton plant leaves was calculated using the following equation (Sumanta *et al.*, 2014):

$$\text{Chlorophyll 'a' (mg/g)} = 13.36 \times A664 - 5.19 \times A649$$

$$\text{Chlorophyll 'b' (mg/g)} = 27.43 \times A649 - 8.12 \times A664$$

$$\text{Carotenoid (mg/g)} = 1000 \times A470 - 2.13 \times \text{Chlo 'a'} - 97.63 \times \text{Chlo 'b'}/209$$

$$\text{Total Chlorophyll} = \text{Chlo 'a'} + \text{Chlo 'b'}$$

The comparative study of physiological and yield-related characteristics in medium-staple cotton parental cultivars and their hybrids progressed under optimum and water stress conditions. The genetic variability in cotton genotypes and inheritance in various traits, depending upon two water regimes, were determined. All the parameters' data recording succeeded on 30 plants each, in the parental cultivars and their F_1 hybrids, and then averaged. In the concerned study, identifying the essential physiological indicators of water metabolism in cotton plants continued with the following methods: The total amount of water in the leaves used the formula according to Tretyakov *et al.* (1990); water retention properties of leaves (Kushnirenko *et al.,* 1970); transpiration rate (Ivanov *et al.,* 1950); and the data on number of chloroplast pigments in the leaves followed the methodology of Sumanta *et al.* (2014). The details on yield-related traits, i.e., boll weight, 1000-seed weight, and seed cotton yield per plant, were also recorded per the standard procedure in all the cotton genotypes.

The dominance coefficient for various traits studied in the cotton F_1 populations was calculated according to the *S. Wright* formula given in the research work of Beil and Atkins (1965):

$$hp = \frac{F_1 - MP}{P - MP}$$

Where:
hp: dominance coefficient
F_1: the evaluated arithmetic mean of the hybrid
MP: the evaluated arithmetic mean of both parents
P: the evaluated arithmetic mean of the best parents

The results obtained based on experiments received statistical analysis.

The determined levels of adaptation of parental cotton cultivars and their F1 hybrids to water deficit conditions employed the method according to Eberhart and Russell (1966.).

RESULTS

In the studied parental cotton cultivars under optimal irrigation water conditions, the highest amount of total water content in the leaves resulted in the cultivar Ishonch (78.8±0.3%). Cultivars Farovon, Listopad, and 108-RF did not differ significantly based on the said trait. However, the lowest water content in the leaves showed in plants of cultivar Elastik (71.5±2.7%), which was statistically different from all other genotypes. In F_1 hybrids, the highest values in terms of total water content in the leaves revealed in the cross combinations, Farovon × Ishonch (85.8±1.5%) and Listopad × Elastik (80.5±1.8%), while the lowest values in the 108-RF × Farovon (67.9±2.1%) and Kupaysin × Elastik (80.5±1.8%) crosses (Figure 1).

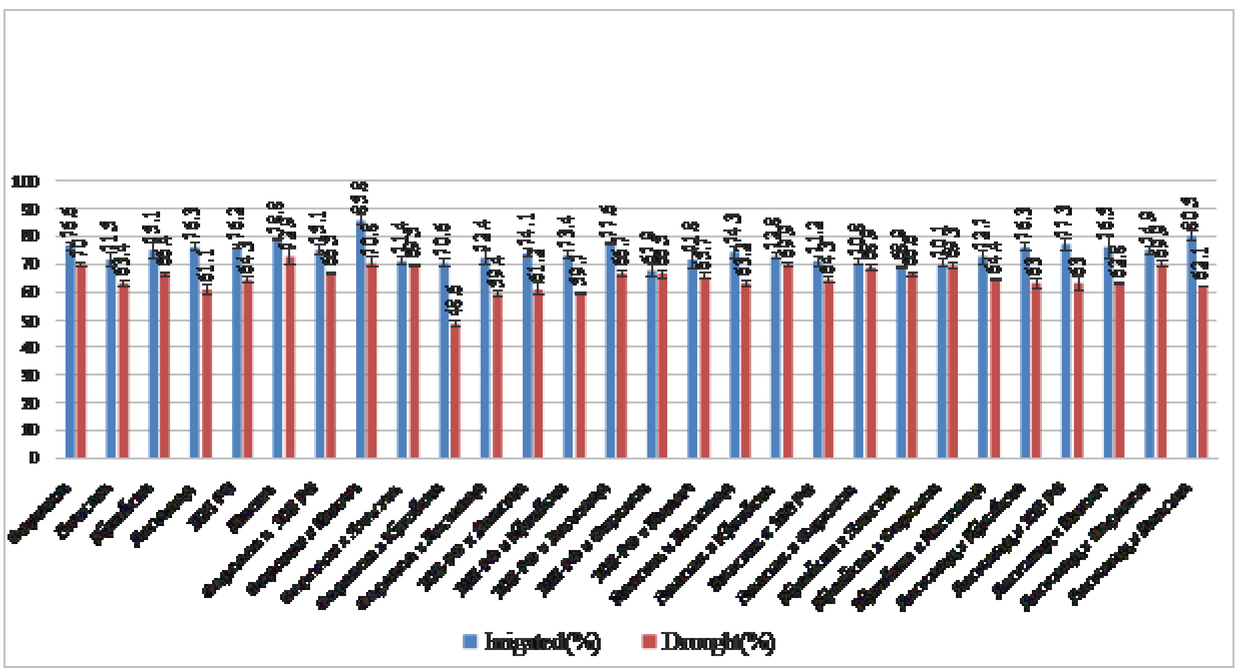

Figure 1. Total water content (%) in leaves of parental cotton cultivars and its inheritance in F_1 hybrids under different water regimes.

A hybrid combination of Cultivars Listopad and 108-RF (76.3±1.5% and 76.2±0.4%, respectively), with a close ratio of total water content in the leaves of their F_1 hybrid Listopad × 108-RF (77.3±1.9%), indicated that the dominance level (hp) at 21.0, with the trait inherited in a positive over-dominance condition. In the F_1 Farovon × Listopad hybrid, where the total water content in the leaves was close to each other (76.6±1.4% and 76.3±1.5%, respectively), with the mean index (72.4±2.2%) and the dominance coefficient at -27.0, exhibited the said trait inheriting the negative over-dominance condition. Overall, under an optimal water supply regime, the total amount of water in the leaves of 22 F_1 hybrids gained inheritance in the following conditions: incomplete dominance of two each cultivars with high and low indicators, complete dominance of one each cultivar with high and low indicators.

In all the parental genotypes and hybrids, the total amount of water in their leaves decreased to varying degrees relative to the optimal water conditions. Under water stress conditions, the highest values of total water content in the leaves showed in the parental cultivars Ishonch (72.9±2.8%) and Farovon (70.0±0.9%), while the lowest values in the cultivar Listopad (61.1±1.6%). In F_1 hybrids, the highest values for total water content in the leaves came from F_1 Farovon × Ishonch, F_1 Elastik × Kupaysin, and F_1 Listopad × Farovon (70.8±2.1%, 69.9±0.8%, and 69.9±1.1%, respectively), while the lowest value in the cross combination Farovon × Kupaysin (48.6±1.3%).

In the F_1 hybrid Farovon × Listopad (59.4±1.1%) of parental cultivars, Farovon and Listopad (70.0±0.9% and 61.1±1.6%, respectively) differed in terms of the total amount of water in the leaves of the plant, and the dominance coefficient (hp) was at -1.4, and the inheritance of the said trait showed negatively dominant. The average amount of total water in the leaves of F_1 Elastik × 108-RF (64.3±1.1%) of Elastik and 108-RF cultivars (63.4±1.1% and 64.3±1.3%, respectively), the dominance coefficient (hp) was 1.0, and the inheritance was in the case of complete dominance of the high-yielding cultivar. Another F_1 cross combination Farovon × Ishonch (66.5±0.6%) of cultivars Farovon and Ishonch (70.0±0.9% and 72.9±2.80%, respectively), has average values for total water content close to each other, and the hp was -0.2, under the incomplete dominance of the cultivar Farovon which had less water content in the inherited leaves. Generally, relative to the optimal water supply regime, the total amount of water in plant leaves decreased from 7.5% to 19.9% in the parental cotton cultivars and 1.1% to 31.2% in F_1 hybrids under the water deficit conditions in the soil.

Results revealed that the total water content in the plant leaves depends not only on the conditions of water supply but also on the genotypic composition. Under different water regimes, the total water content in plant leaves was inherited differently in F_1 hybrids, where the dominance coefficient (hp) varies depending on the water supply conditions and the composition of the parental genotypes of the hybrids.

Transpiration is the evaporation of water through the leaves of plants. It is a physical process where water passes into the intercellular vapor state, diffuses through the leaf openings, and then shoots into the environment. The transpiration process depends on the amount and size of the water-permeable tubes, the number of leaflets, the thickness of the cuticle layer, the condition of the protoplasmic colloids, and the concentration of cell sap. Water rises along the stem of the plant, and as a result of transpiration, there is a suction force in the leaf cell, which absorbs the water from the root hairs and carries them to the leaf (Beknazarov, 2009). Another importance of transpiration comes from aiding the transport of minerals absorbed by the root hairs with water. In addition, transpiration lowers the temperature of the leaves and protects them from overheating.

In this study, determining the indicators of transpiration rate during the flowering-harvesting period of cotton cultivars and F_1 hybrid plants under different water regime conditions took place. Under optimal water conditions, in terms of transpiration rate in the leaves of cotton cultivars, a clear advantage showed in the cultivar 108-RF (194.9±3.9 mg/g.s), while the lowest value in the cultivar Farovon (121.9±2.6 mg/g.s). However, the cultivars Elastik, Ishonch, and Kupaysin revealed the intermediate values 141.0±3.1, 143.7±1.7, and 146.2±0.8 mg/g.s, respectively (Figure 2).

In F_1 hybrids, the highest transpiration rate resulted in F_1 Elastik × 108-RF, Kupaysin × Farovon, and 108-RF × Listopad (195.2±2.6, 193.8±2.4, and 180.7±2.4 mg/g.s, respectively), while the lowest values in the cross combinations, Listopad × Farovon, Farovon × Kupaysin, and Farovon × Ishonch

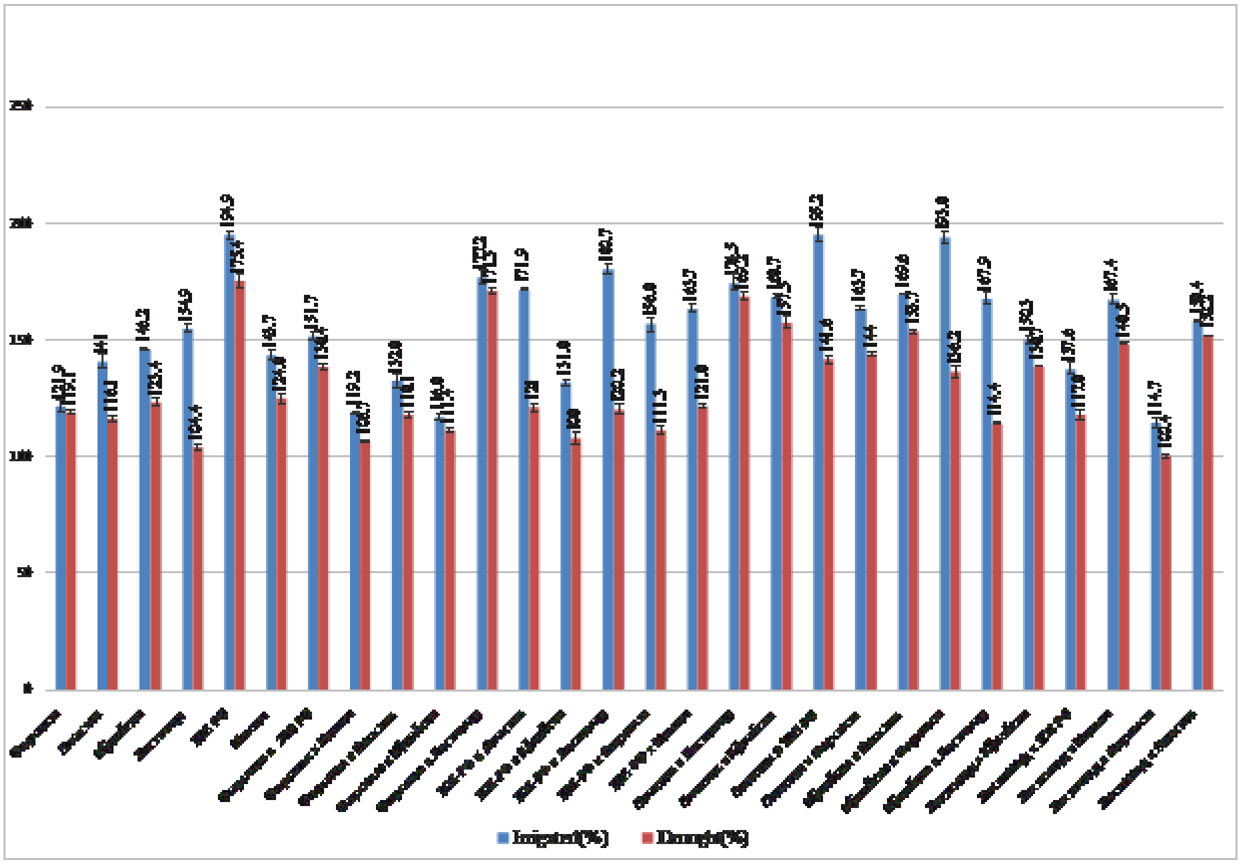

Figure 2. Transpiration rate (mg/g.h) in the leaves of parental cotton cultivars and its inheritance in F_1 hybrids under different water regimes.

(114.7±4.2, 116.8±1.3, and 119.2±0.6 mg/g.s, respectively). In F_1 hybrid Farovon × 108-RF, the cultivar Farovon with the lowest maternal parent and cultivar 108-RF with the highest paternal indicator, the transpiration rate scored at 151.7±1.5 mg/g.s. In the said hybrid, the inheritance of the trait took place in a state of negative incomplete dominance (hp = -0.2). The parental cultivars (141.0±3.1 and 146.2±0.8 mg/g.s, respectively) of the F_1 hybrid Elastik and Kupaysin, which do not differ reliably from each other in terms of trait index, gave the transpiration rate of 168.7±0.7 mg/g.s and inherited the trait in a positive over-dominance (hp = 9.7). Mainly, under an optimal water regime, the transpiration rate in 22 cultivars of F_1 hybrids was inherited in the following states: Positive over-dominance in nine cultivars, negative over-dominance in five cultivars, complete dominance in one cultivar with high indicators, complete dominance in three cultivars with low indicators, and intermediate dominance in one combination.

Results also revealed that the transpiration rate in the leaves of all the cotton genotypes studied concerning the optimal water regime and under water deficit conditions decreased to varying degrees, i.e., lack of soil moisture during flowering-yielding stages harmed the water exchange processes in the parental cultivars and their F_1 hybrids. The cultivar 108-RF evaporated more water (175.4±2.6 mg/g.s) than other cotton cultivars, even under water deficit conditions, as under optimal water supply. Relatively low transpiration rates appeared in the cultivar Listopad (104.4±1.1 mg/g.s). The highest transpiration rate occurred in F_1 hybrids, Farovon × Listopad (171.3±1.5 mg/g.s) and Elastik × Listopad (171.3±1.5 mg/g.s). However, F_1 hybrids, Listopad × Farovon (100.4±0.9 mg/g.s) and Farovon × Ishonch (106.7±0.3 mg/g.s) revealed the least transpiration rate compared with other hybrids.

The parental cultivar 108-RF (175.4±2.6 mg/g.s) provided the highest transpiration rate, while cultivar Listopad showed the lowest transpiration rate (104.4±1.1 mg/g.s). Their hybrid 108-RF × Listopad had a medium transpiration rate (120.2±2.2 mg/g.s), revealing that the said trait was inherited in a negative incomplete dominance (hp = -0.6). The parental cultivars Elastik and Farovon not differing reliably from each other in terms of transpiration rate (116.1±1.4 and 119.1±1.0 mg/g.s, respectively), their hybrid result in 144.0±1.0mg/g.s, having a dominance coefficient (hp) of 17.6, and the said trait was inherited in a positive over-dominance. Thus, under the water deficit regime, the attribute of transpiration rate in 22 cultivars of F_1 hybrids was inherited in the following states: Positive over-dominance in nine cultivars, negative over-dominance in six cultivars, incomplete dominance in two cultivars with high indicators, and incomplete dominance in five cultivars with low markers.

The transpiration rate decreased from 10.0% to 32.6% in the parental cultivars and from 3.0% to 33.5% in F_1 hybrids under water stress conditions. The latest results further showed that transpiration in cotton plants gets maximized under optimal water regime conditions, with sufficient moisture in the soil. As known, the high rate of transpiration increases the process of water and nutrient uptake by plants accelerating the diffusion of CO_2 into the leaf mesophyll and accelerating photosynthesis that synthesizes many organic substances. The high plant biomass under water deficit conditions explains this. The decrease in transpiration intensity in the parental genotypes and their hybrids under drought conditions is associated with loss of turgor and leaf wilting due to a decline in the total amount of water and free water in the plant leaves.

The reported study further looked into the amount of chlorophyll 'a' and 'b,' total chlorophyll, and carotenoids from chloroplast pigments during the flowering-yielding period of the parental cultivars and their F_1 hybrids in upland cotton.

Chlorophyll 'a'

Among the parental cotton cultivars with an optimal water supply, the cultivar Kupaysin displayed the highest value of chlorophyll 'a' (2.81±0.02 mg/g), while the lowest values by the cultivars Listopad and 108-RF (1.91±0.05 and 1.99±0.02 mg/g, respectively) (Table 1). Other cotton cultivars did not differ significantly in terms of chlorophyll 'a' content. Among the F_1 hybrids, the highest value of chlorophyll 'a' showed in the cross combinations Kupaysin × Elastik and Elastik × Listopad (2.90±0.05 and 2.62±0.07 mg/g, respectively) and the lowest value in the F1 hybrids, Farovon × 108-RF and Listopad × Ishonch (1.89±0.02 and 1.99±0.02 mg/g, respectively).

For chlorophyll 'a,' in the F_1 hybrid Kupaysin × Listopad (2.21±0.08 mg/g), the parental cultivar Kupaysin consisted as the highest maternal indicator, and the cultivar Listopad as the lowest paternal indicator (2.81±0.02 and 1.91±0.05 mg/g. respectively), and in the said hybrid the inheritance of the said trait took place in a negative incomplete dominance (hp = -0.3). In F_1 hybrid Farovon × Elastik (2.32±0.01 mg/g), the parental cultivars (2.08±0.02 and 2.25±0.01mg/g, respectively) do not differ reliably from each other in terms of chlorophyll 'a,' and the trait inheritance showed a positive over-dominance (hp = 1.8). Thus, under optimum irrigation conditions, the chlorophyll 'a' content in 22 cultivars of F_1 hybrids was inherited in the following states: Positive over-dominance in eight cultivars, negative over-dominance in 10 cultivars, incomplete dominance in two cultivars with high indicators, and incomplete dominance in five cultivars with low indexes.

Compared with the optimal water regime, the chlorophyll 'a' in the leaves of studied cotton genotypes decreased to varying degrees under water deficit conditions. Notably, the lack of moisture in the soil during the flowering and harvesting period negatively affects the photosynthesis processes of parental cotton cultivars and their F_1 hybrids. Under optimum water supply and scarcity conditions, the cultivar Kupaysin contains more chlorophyll 'a' (2.78±0.02 mg/g) than other cultivars. However, the relatively low chlorophyll 'a' content in the cultivar Listopad only reached 1.69±0.01 mg/g. The higher chlorophyll 'a' content found in the F_1 hybrids Elastik × 108-RF and Farovon × Elastik measured 2.26±0.08 and 2.22±0.09 mg/g, respectively, while low chlorophyll 'a' observed in the F_1 hybrid Kupaysin × Listopad scored 1.52±0.02 mg/g.

The F_1 hybrid Kupaysin × Farovon (1.92±0.06 mg/g), obtained from cultivars Kupaysin and Farovon, which differ reliably from each other in terms of chlorophyll 'a' content (2.78±0.02 and 1.99±0.01 mg/g, respectively), the dominance coefficient (hp)

Table 1. Inheritance of chlorophyll 'a' and 'b' (mg/g) in parental cultivars and their F_1 hybrids in upland cotton under different water regimes.

No.	Parental cultivars & F_1 hybrids	Chlorophyll 'a' (mg/g)					Chlorophyll 'b' (mg/g)				
		Irrigated	hp	Drought	hp	Levels of adaptation (%)	Irrigated	hp	Drought	hp	Levels of adaptation (%)
1	Farovon	2.08±0.02	-	1.99±0.01	-	-4.3	0.92±0.07	-	0.49±0.03	-	-46.7
2	Elastik	2.25±0.01	-	2.14±0.06	-	-4.9	0.79±0.03	-	0.65±0.09	-	-17.7
3	Kupaysin	2.81±0.02	-	2.78±0.02	-	-1.1	0.71±0.08	-	0.60±0.01	-	-15.5
4	Listopad	1.91±0.05	-	1.69±0.01	-	-11.5	0.71±0.03	-	0.68±0.05	-	-4.2
5	108-RF	1.99±0.01	-	1.83±0.08	-	-8	1.01±0.07	-	0.98±0.01	-	-3
6	Ishonch	2.38±0.07	-	2.14±0.05	-	-10.1	0.67±0.01	-	0.63±0.06	-	-6
7	Farovon × 108-RF	1.89±0.02	-3.2	1.85±0.02	-0.8	-2.1	0.72±0.04	-5.4	0.65±0.04	-0.3	-9.7
8	Farovon × Ishonch	2.10±0.02	-0.9	2.01±0.01	-0.7	-4.3	0.71±0.01	-0.7	0.58±0.02	0.3	-18.3
9	Farovon × Elastik	2.32±0.01	1.8	2.22±0.09	2.1	-4.3	0.77±0.01	-1.3	0.69±0.09	1.5	-10.4
10	Farovon × Kupaysin	2.26±0.01	-0.5	1.97±0.01	-1.1	-12.8	0.87±0.06	0.5	0.70±0.01	2.8	-13
11	Farovon × Listopad	2.20±0.03	2.4	1.65±0.07	-1.3	-25	0.83±0.02	0.1	0.80±0.07	2.3	-3.6
12	108-RF × Elastik	2.09±0.01	-0.2	1.78±0.03	-1.3	-14.8	0.75±0.07	-1.4	0.63±0.03	-1.1	-16
13	108-RF × Kupaysin	2.33±0.03	-0.2	1.65±0.03	-1.4	-29.2	0.85±0.08	-0.1	0.82±0.02	0.2	-3.5
14	108-RF × Listopad	2.47±1.01	13	1.65±0.06	-1.6	-33.2	1.02±0.04	1.1	0.96±0.05	0.9	-5.9
15	108-RF × Farovon	2.32±0.01	6.3	1.75±0.03	-2	-24.6	0.92±0.09	-1	0.81±0.01	0.3	-12
16	108-RF × Ishonch	2.27±0.03	0.4	1.67±0.01	-2	-26.4	0.94±0.02	0.6	0.75±0.01	-0.3	-20.2
17	Elastik × Listopad	2.62±0.07	3.2	2.10±0.09	0.8	-19.8	1.07±0.01	8	0.79±0.01	8.3	-26.2
18	Elastik × Kupaysin	2.21±0.01	-1.1	2.14±0.01	-1	-3.2	0.80±0.03	1.2	0.65±0.01	1	-18.8
19	Elastik × 108-RF	2.28±0.07	1.2	2.26±0.08	1.8	-0.9	0.84±0.05	-0.5	0.77±0.08	-0.3	-8.3
20	Elastik × Farovon	2.18±0.01	0.2	2.12±0.01	0.7	-2.8	0.80±0.02	-0.8	0.72±0.07	1.9	-10
21	Kupaysin × Elastik	2.90±0.05	1.3	2.43±0.08	-0.1	-16.2	1.07±0.01	8	0.84±0.06	8.6	-21.5
22	Kupaysin × Farovon	2.34±0.05	-0.3	1.92±0.06	-1.2	-17.9	0.88±0.01	0.6	0.87±0.03	5.9	-1.1
23	Kupaysin × Listopad	2.21±0.08	-0.3	1.52±0.02	-1.3	-31.2	0.89±0.09	0.2	0.84±0.09	5	-5.6
24	Listopad × Kupaysin	2.12±0.06	-0.5	1.95±0.02	-0.5	-8	0.84±0.05	0.1	0.81±0.07	4.2	-3.6
25	Listopad × 108-RF	2.10±0.02	3.8	2.02±0.01	3.7	-3.8	0.78±0.06	-0.5	0.67±0.03	-1.1	-14.1
26	Listopad × Ishonch	1.99±0.02	-0.7	1.62±0.01	-1.3	-18.6	0.85±0.06	8	0.78±0.01	5	-8.2
27	Listopad × Farovon	2.02±0.09	0.3	1.96±0.03	0.8	-2.9	0.88±0.01	0.6	0.68±0.04	1	-22.7
28	Listopad × Elastik	2.22±0.01	0.8	1.73±0.09	-0.8	-22.1	1.00±0.01	6.2	0.93±0.05	17.7	-7

was -1.2, and the inheritance of the said trait showed a negative over-dominance. In the F_1 hybrid Listopad × 108-RF (2.02±0.01 mg/g), obtained from parental cultivars Listopad and 108-RF cultivars (1.69±0.01 and 1.83±0.08 mg/g, respectively), revealed close to each other in terms of chlorophyll 'a' content, the dominance coefficient (hp) was 3.7, and the inheritance in a positive over-dominance state. Thus, under the water deficit conditions, the chlorophyll 'a' content in 22 cultivars of F_1 hybrids was inherited in the following states: (Positive over-dominance in three cultivars, negative over-dominance in 10 cultivars, incomplete dominance in three cultivars with high indicators, incomplete dominance in five cultivars with low indicators, and complete dominance in one cultivar with low marks). The coefficient of adaptation, in terms of chlorophyll 'a' content in the leaves, ranged from -4.3% to -11.5% in parental cultivars and -0.9% to -33.2% in F_1 hybrids.

Chlorophyll 'b'

Among the parental cotton cultivars with optimum irrigation conditions, the highest value of chlorophyll 'b' appeared in the cultivar 108-RF (1.01±0.07 mg/g) (Table 1), while the lowest value in the cultivar Ishonch (0.67±0.01 mg/g). Among the F_1 hybrids, the highest value of chlorophyll 'b' came from the cross combinations Elastik × Listopad and Kupaysin × Elastik (1.07±0.01 and 1.07±0.01 mg/g, respectively). Inversely, the lowest chlorophyll 'b' value showed in F_1 hybrids Farovon × Ishonch and Farovon × 108-RF (0.71±0.01 and 0.71±0.04 mg/g, respectively).

In the F_1 hybrid 108-RF × Ishonch (0.81±0.01 mg/g), which included cultivar 108-RF with the highest maternal value and cultivar Ishonch with the lowest paternal value (2.81±0.02 and 1.91±0.05 mg/g, respectively) of chlorophyll 'b,' the inheritance of the said trait took place in an incomplete positive dominance (hp = 0.3). In cross combination Listopad × Ishonch (0.85±0.06 mg/g), the parental cultivars Listopad and Ishonch (0.71±2.3 and 0.67±1.1 mg/g, respectively) showed close to each other in terms of chlorophyll 'b,' with the trait inherited in a positive over-dominance (hp = 8.0). Thus, with an optimal water regime, the trait of chlorophyll 'b' content in 22 cultivars of F_1 hybrids was inherited in the following states: Positive over-dominance with heterosis in six cultivars, negative over-dominance in four cultivars, incomplete dominance in seven cultivars with high indicators, incomplete dominance in four cultivars with low indicators, and complete dominance in one cultivar with low indicators. The chlorophyll 'b' content in the leaves of parental cultivars and their F_1 hybrids decreased to different extents under water deficit conditions compared with optimal water supply conditions. In parental genotypes, the highest amount of chlorophyll 'b' content came about in the leaves of cultivar 108-RF (0.98±0.01 mg/g), while the lowest value in the cultivar Farovon (0.49±0.03 mg/g) under optimum irrigation conditions.

Under water stress conditions, the highest chlorophyll 'b' content recorded in the F_1 hybrids 108-RF × Listopad and Listopad × Elastik measured 0.96±0.05 and 0.93±0.05 mg/g, respectively. However, the lowest values for chlorophyll 'b' came from the F_1 hybrids 108-RF × Elastik, Farovon × 108-RF, and Elastik × Kupaysin (0.63±0.03, 0.65±0.04, and 0.65±0.01 mg/g, respectively). In F_1 hybrid 108-RF × Elastik (0.94±0.02 mg/g), which included cultivar 108-RF with the highest maternal value and cultivar Elastik with the lowest paternal indicator (0.98±0.01 and 0.49±0.03 mg/g, respectively), the inheritance of the said trait took place in an incomplete positive dominance (hp = 0.3). In the F_1 Listopad × Elastik (0.93±0.05 mg/g), the parental cultivars Listopad and Elastik showed close to each other in terms of trait indicators (0.68±0.05 and 0.65±0.09 mg/g, respectively), the said trait inherited in a positive over-dominance (hp = 17.7).

Thus, under the water deficit conditions, the trait of chlorophyll 'b' content in 22 cultivars of F_1 hybrids was inherited in the following states: Positive over-dominance in 12 cultivars, negative dominance in two cultivars, incomplete dominance in four cultivars with high indicators, incomplete dominance in three cultivars with low indicators, and complete dominance in one cultivar with high indicators). Compared with the optimal water regime, the amount of chlorophyll 'b' in plant leaves decreased from 3.0% to 46.7% in the parental cultivars, and from 1.1% to 26.2% in their F_1 hybrids under water deficit conditions. This situation shows that the chlorophyll 'b' content in plant leaves depends not only on irrigation water, but also on the genotypic composition. The obtained results showed that the chlorophyll 'b' trait was inherited differently in F_1 hybrids under two water regimes, and the variations in the dominance coefficient (hp) depend on irrigation conditions, as well as, the genetic make-up of the parental genotypes in the hybrids.

Total chlorophyll

The study on total chlorophyll content in the leaves of parental cultivars and their F_1 hybrids also proceeded during the flowering-harvest period of cotton under different water regimes. Under optimum irrigation conditions, the cultivar Ishonch showed the highest total chlorophyll content (3.06±0.01 mg/g), while the lowest indicator in the cultivar Kupaysin (2.57±0.09 mg/g) (Table 2). In F_1 hybrids, the highest total chlorophyll found in Elastik × Listopad and 108-RF × Listopad valued at 3.68±0.01 and 3.49±0.01 mg/g, respectively. Conversely, the lowest value for the said trait shown in the F_1 hybrids Farovon × 108-RF and Listopad × 108-RF (2.61±0.07 and 2.79±0.02 mg/g, respectively).

In F_1 hybrid Farovon × Kupaysin (3.13±0.04 mg/g), the parental cultivars Farovon and Kupaysin (3.00±0.02 mg/g and 2.57±0.09 mg/g, respectively) are reliably different from each other in terms of total chlorophyll in plant leaves, with dominance coefficient of 1.6 and the inheritance of the said trait took place in a positive over-dominance. The total chlorophyll content in the leaves of F1 hybrid Farovon × 108-RF marked at 2.61±0.07 mg/g, yet, its parental cultivars Farovon and 108-RF recorded the same values (3.00±0.02 and 3.00±0.0 mg/g, respectively), with the dominance coefficient at -0.4 and the said trait inherited in an incomplete dominance of the cultivars with low indicators.

Thus, under an optimal water regime, the total chlorophyll trait in 22 cultivars of F_1 hybrids was inherited in the following states: Positive over-dominance in 14 cultivars, negative over-dominance in one cultivar, incomplete dominance in three cultivars with high indicators, incomplete dominance in three cultivars with low indicators, and intermediate dominance in one cultivar). Total chlorophyll content decreased to varying degrees in all studied cotton genotypes under water scarcity conditions compared with the optimal water supply. In cotton cultivars under stress conditions, the highest total chlorophyll in leaves was shown by the cultivar 108-RF (2.81±0.04 mg/g), while the lowest value in the cultivar Elastik (2.09±0.06 mg/g). In F_1 hybrids, the Elastik × Listopad and Elastik × 108-RF combinations recorded the highest total chlorophyll (3.02±0.09 and 3.01±0.07 mg/g, respectively). Though, the lowest values were observed in the cross combinations Kupaysin × Listopad, Kupaysin × Elastik, 108-RF × Ishonch, and F_1 108-RF × Kupaysin (2.40±0.03, 2.42±0.02, 2.43±0.07, and 2.48±0.05 mg/g), respectively.

In F_1 108-RF × Elastik (2.73±0.01mg/g) combination, the cultivar 108-RF with the highest maternal trait and cultivar Elastik with the lowest paternal trait (2.81±0.04 and 2.09±0.06 mg/g, respectively), the total chlorophyll content was inherited in an incomplete positive dominance (hp = 0.8). In the F_1 hybrid 108-RF × Ishonch (2.43±0.07 mg/g), with its parental genotypes 108-RF and Ishonch, showed close to each other in terms of total chlorophyll (2.81±0.04 and 2.78±0.01mg/g, respectively), with dominance coefficient of -24.3, and the heredity of the said trait took place in a negative over dominance.

Overall, under water deficit conditions, the total chlorophyll content in leaves was inherited in positive super dominance in 12 of 22 F_1 hybrids, negative super dominance in two, incomplete dominance of the high-performance cultivar in five, and incomplete dominance of the low-performance cultivar in three. Thus, under the water scarcity regime, the total chlorophyll in 22 cultivars of F_1 hybrids was inherited in the following states: Positive over-dominance in 12 cultivars, negative over-dominance in two cultivars, incomplete dominance in five cultivars with high indicators, and incomplete dominance in three cultivars with low indicators.

Carotenoids

The study of the carotenoid content also took place in the leaves of medium-staple upland cotton parental cultivars and their F_1 hybrids under different irrigation water regimes (Table 2). According to the present results, in terms of carotenoid content in the leaves under optimal water conditions, the highest carotenoid content recorded in the cultivar Ishonch measured 0.59±0.06 mg/g, and the lowest index observed in the cultivar 108-RF at 0.39±0.09 mg/g. In F_1 hybrids, the highest carotenoid content appeared in the cross combinations, 108-RF × Elastik and Kupaysin × Elastik, with values of 0.57±0.07 and 0.57±0.03 mg/g, respectively. On the other hand, the lowest index observed in the F_1 hybrids, Listopad × Ishonch, Listopad × 108-RF, Listopad × Kupaysin, and Listopad × Farovon, gave the values of 0.41±0.02, 0.42±0.05, 0.43±0.03, and 0.43±0.07 mg/g, respectively.

Table 2. Inheritance of total chlorophyll and carotenoid content (mg/g) in parental cultivars and their F_1 hybrids in upland cotton under different water regimes.

No.	Parental cultivars & F_1 hybrids	Total chlorophyll (mg/g)					Carotenoid (mg/g)				
		Irrigated	hp	Drought	hp	Levels of adaptation %	Irrigated	hp	Drought	hp	Levels of adaptation %
1	Farovon										
2	Elastik	2.78±0.01	-	2.09±0.06	-	-24.8	0.42±0.08	-	0.57±0.07	-	35.7
3	Kupaysin	2.57±0.09	-	2.53±0.03	-	-1.6	0.43±0.05	-	0.53±0.04	-	23.3
4	Listopad	2.64±0.01	-	2.36±0.08	-	-10.6	0.46±0.03	-	0.50±0.09	-	8.7
5	108-RF	3.00±0.05	-	2.81±0.04	-	-6.3	0.39±0.09	-	0.45±0.06	-	15.4
6	Ishonch	3.06±0.01	-	2.78±0.01	-	-9.2	0.59±0.06	-	0.64±0.02	-	8.5
7	Farovon × 108-RF	2.61±0.07	1.1	2.56±0.02	-0.2	-1.9	0.45±0.09	0.7	0.46±0.03	-0.9	2.2
8	Farovon × Ishonch	2.81±0.03	4.1	2.73±0.08	0.8	-2.8	0.46±0.08	-1	0.52±0.03	-0.1	13
9	Farovon × Elastik	3.09±0.02	0.8	2.89±0.09	1.6	-6.5	0.54±0.06	5	0.65±0.07	1.3	20.4
10	Farovon × Kupaysin	3.13±0.04	-1.8	2.88±0.06	5.7	-8	0.47±0.03	1.7	0.58±0.01	-0.1	23.4
11	Farovon × Listopad	3.03±0.01	-3.4	2.55±0.01	18	-15.8	0.48±0.03	0	0.51±0.01	-0.9	6.3
12	108-RF × Elastik	2.85±0.03	16.5	2.73±0.01	0.8	-4.2	0.57±0.07	11	0.64±0.05	6.6	12.3
13	108-RF × Kupaysin	3.18±0.09	2	2.48±0.05	-1.4	-22	0.52±0.01	5.5	0.67±0.02	4.5	28.8
14	108-RF × Listopad	3.49±0.01	1.8	2.97±0.03	1.7	-14.9	0.51±0.04	2.4	0.62±0.08	5.8	21.6
15	108-RF × Farovon	3.24±0.02	2.4	2.56±0.04	-0.2	-21	0.50±0.07	2.1	0.64±0.03	1	28
16	108-RF × Ishonch	3.21±0.01	2.2	2.43±0.07	-24.3	-24.3	0.48±0.02	-0.1	0.56±0.03	0.2	16.7
17	Elastik × Listopad	3.68±0.01	1.5	3.02±0.09	5.9	-17.9	0.54±0.07	5	0.64±0.06	0.3	18.5
18	Elastik × Kupaysin	3.01±0.05	-0.2	2.90±0.05	2.7	-3.7	0.47±0.01	9	0.48±0.07	-3.5	2.1
19	Elastik × 108-RF	3.12±0.02	9.6	3.01±0.07	1.6	-3.5	0.46±0.03	3.7	0.50±0.01	-2.5	8.7
20	Elastik × Farovon	2.98±0.02	1.2	2.81±0.08	4	-5.7	0.47±0.04	1.5	0.51±0.01	-2.7	8.5
21	Kupaysin × Elastik	2.97±0.09	0.6	2.42±0.02	0.5	-18.5	0.57±0.03	29	0.61±0.02	3	7
22	Kupaysin × Farovon	3.22±0.06	1.2	2.66±0.03	2.7	-17.4	0.47±0.06	1.7	0.51±0.05	-1.4	8.5
23	Kupaysin × Listopad	3.05±0.07	1.6	2.40±0.03	-0.5	-21.3	0.46±0.03	1	0.55±0.07	2.3	19.6
24	Listopad × Kupaysin	2.95±0.07	2.1	2.76±0.01	3.7	-6.4	0.43±0.03	-1	0.52±0.08	0.3	20.9
25	Listopad × 108-RF	2.79±0.02	3.4	2.68±0.03	0.4	-3.9	0.42±0.05	-0.1	0.53±0.08	2.2	26.2
26	Listopad × Ishonch	2.84±0.01	6.6	2.75±0.07	0.9	-3.2	0.41±0.02	-1.8	0.51±0.06	-0.9	24.4
27	Listopad × Farovon	2.90±0.08	6.2	2.85±0.06	48	-1.7	0.43±0.07	-0.1	0.62±0.01	0.7	44.2
28	Listopad × Elastik	3.23±0.09	1.1	2.65±0.09	3.1	-18	0.45±0.8	-1.2	0.55±2.6	0.4	22.2

The F_1 hybrid 108-RF × Ishonch (0.48±0.02 mg/g), obtained from the cultivar 108-RF with the lowest maternal trait and cultivar Ishonch with the highest paternal trait, the trait was inherited in a negative incomplete dominance (hp = -0.1). In F_1 hybrid Kupaysin × Elastik (0.57 ±0.03 mg/g) obtained from cultivars Kupaysin and Elastik, which do not differ from each other in terms of carotenoid content (0.43±0.05 and 0.42±0.08 mg/g, respectively), the dominance coefficient (hp) was 29.0, with the heredity transmitted through positive over dominance. In a cross combination of Farovon × Listopad (0.48±0.03 mg) of cultivars Farovon and Listopad (0.46±0.02 and 0.46±0.03 mg/g, respectively), which do not differ in terms of carotenoids content in the leaves, the average value of the trait gained inheritance in a positive over-dominance.

Under an optimal water regime, the carotenoid content trait in 22 cultivars of F_1 hybrids was inherited in the following states: Positive over-dominance in 12 cultivars, negative over-dominance in two cultivars, incomplete dominance in one cultivar with high indicators, incomplete dominance in three cultivars with low indicators, complete dominance in one cultivar with high indicators, complete dominance in two cultivars with low indicators, and intermediate dominance in one cultivar.

Carotenoid content increased to varying degrees in the cotton genotypes under water deficit conditions compared with optimal water supply conditions. In this regard, the highest values of carotenoid content observed in cultivars Farovon and Ishonch rated at 0.64±0.03 and 0.64±0.03 mg/g, respectively, and the lowest value in 108-RF cultivar at 0.45±0.06 mg/g. In conditions of water scarcity in the soil, the highest values of carotenoid content were shown by the F_1 hybrids 108-RF × Kupaysin and Farovon × Elastik (0.67±0.02 and 0.65±0.07 mg/g, respectively), while the lowest values in F_1 hybrids, Farovon × 108-RF and Elastik × Kupaysin (0.46±0.03 and 0.48±0.07 mg/g, respectively).

In the F_1 hybrid 108-RF × Farovon (0.64±0.03 mg/g), obtained from the cultivar 108-RF with the lowest maternal trait and cultivar Farovon with the highest paternal trait, the trait inheritance took place in complete dominance of the cultivar Farovon with the highest dominance coefficient (hp = 1.0). In the hybrid Kupaysin × Listopad (0.55±0.07 mg/g) obtained from cultivars Kupaysin and Listopad cultivars, which are close to each other in terms of trait parameters (0.53±0.04 and 0.50±0.09 mg/g, respectively), the dominance coefficient was 2.3, and the heredity took place in a positive over dominance.

Under the water scarcity regime, the carotenoid content in 22 cultivars of F_1 hybrids was inherited in the following states: Positive over-dominance in seven cultivars, negative over-dominance in four cultivars, incomplete dominance in five cultivars with high indicators, incomplete dominance in five cultivars with low indicators, and complete dominance in one cultivar with high indicators). Thus, the carotenoid content increased from 8.5% to 39.1% in the parental cotton cultivars, while 2.1% to 44.2% in the F_1 hybrids under the water deficit conditions compared with the optimal water regime in the soil. This situation showed that parental cotton cultivars and their hybrids received protection against water scarcity through different levels of carotenoid enhancement in plant leaves.

Seed cotton yield

One of the main economic characteristics of the cotton plant is its time of harvest in September. Therefore, the study on seed cotton yield in the parental cultivars and their F_1 hybrids ensued (Table 3). Under optimal water conditions, the parental cultivars Kupaysin and Farovon had the highest seed cotton yield per plant (76.1±4.0 and 62.9±3.0 g, respectively), while relatively low yield came from cultivars Elastik and 108-RF (51.5±2.2 and 51.3±3.2 g, respectively). Among the F_1 hybrids, the seed cotton yield ranged from 50.4±1.6 g (F_1 Elastik × Farovon) to 88.4±5.2 g (F_1 108-RF × Kupaysin), and 18 F_1 hybrids obtained a higher seed cotton yield than their parental cultivars.

In the F_1 hybrid Kupaysin × Elastik (71.5±2.3 g), the cultivars Kupaysin and Elastik reliably differ from each other in terms of seed cotton yield (76.1±4.0 and 51.5±2.2 g, respectively), and the cultivar Kupaysin observed with a relatively high index of heredity had an incomplete dominance (hp = 0.6). In F_1 hybrid 108-RF × Elastik, the parental cultivars 108-RF and Elastik do not reliably differ in terms of seed cotton yield, and the said trait inherited a positive extreme over dominance (hp = 16.5).

Under water deficit conditions, the seed cotton yield in 22 cotton cultivars of F_1 hybrids was inherited in the following states: Incomplete dominance in two cultivars with high indicators, incomplete dominance in one

Table 3. Inheritance of yield-related traits in parental cultivars and their F_1 hybrids in upland cotton under different water regimes.

No.	Parental cultivars & F_1 hybrids	Seed cotton yield per plant (g)					Boll weight (g)					1000-seed weight (g)				
		Irrigated	hp	Drought	hp	Levels of adaptation (%)	Irrigated	hp	Drought	hp	Levels of adaptation (%)	Irrigated	hp	Drought	hp	Levels of adaptation (%)
1	Farovon	62.9±3.0	-	57.6±1.1	-	-8.4	5.7±0.1	-	5.1±0.2	-	-10.5	122.7±1.1	-	113.5±2.3	-	-7.5
2	Elastik	51.5±2.2	-	36.5±1.7	-	-29.1	5.6±0.4	-	5.3±0.3	-	-1.8	119.8±0.6	-	100.6±0.3	-	-16
3	Kupaysin	76.1±4.0	-	52.7±1.5	-	-30.8	6.1±0.8	-	5.8±0.2	-	-7.9	120.6±0.6	-	110.0±0.7	-	-8.8
4	Listopad	57.2±1.3	-	47.3±1.1	-	-17.3	5.7±0.3	-	5.7±0.3	-	0	132.6±0.8	-	105.7±0.3	-	-20.3
5	108-RF	51.3±3.2	-	50.8±1.4	-	-0.9	5.6±0.6	-	5.3±0.4	-	-5.4	118.9±0.2	-	110.3±0.9	-	-7.2
6	Ishonch	60.1±2.1	-	58.7±1.7	-	-2.3	6.0±0.3	-	5.9±0.2	-	-3.3	128.6±0.3	-	111.5±0.9	-	13.3
7	Farovon × 108-RF	63.4±3.1	1.1	43.1±1.8	-3.3	-32	6.5±0.4	11.2	5.5±0.4	3	-15.4	108.2±0.2	-6.6	104.3±0.7	1.5	-3.6
8	Farovon × Ishonch	67.3±3.6	4.1	52.3±1.0	-10.6	-22.3	6.2±0.1	11.5	6.0±0.9	2	-3.2	118.9±0.8	-2.3	92.9±0.6	-11.5	-21.6
9	Farovon × Elastik	61.9±1.9	0.8	46.6±4.1	0	-24.7	5.5±0.2	-3	5.3±0.5	-3	-3.6	121.2±0.4	-0.1	110.0±0.5	0.5	-9.2
10	Farovon × Kupaysin	57.3±1.9	-1.8	43.3±1.6	-4.8	-24.4	6.9±0.8	3	6.2±0.2	2.1	-10.1	125.0±0.6	3.2	117.0±0.7	3	-6.4
11	Farovon × Listopad	50.5±1.7	-3.4	48.3±1.2	-0.8	-4.4	6.1±0.6	1.4	4.4±0.2	-3.3	-38	117.5±0.9	-2.1	86.0±0.3	-0.6	-26.8
12	108-RF × Elastik	67.9±4.6	16.5	45.8±1.3	0.3	-32.6	5.1±0.4	-0.5	4.1±0.2	-7	-19.6	126.7±1.0	16.3	89.0±0.1	-3.4	-29.8
13	108-RF × Kupaysin	88.4±5.2	2	41.8±1.3	-10.5	-52.7	5.7±0.4	-0.7	3.9±0.7	-6.6	-31.6	117.2±0.9	-3	90.0±1.5	-58.4	-23.2
14	108-RF × Listopad	59.5±1.2	1.8	48.6±1.8	-0.3	-18.3	5.9±0.2	5	4.9±0.8	-3	-17	122.7±0.8	-0.4	113.5±1.9	2.4	-7.5
15	108-RF × Farovon	71.1±1.6	2.4	44.3±1.2	-2.9	-37.7	6.7±0.7	21	6.5±0.3	13	-3	139.5±0.2	9.8	109.5±0.2	-1.5	-21.5
16	108-RF × Ishonch	65.3±1.1	2.2	44.1±1.2	-2.7	-32.5	6.8±0.7	3.8	6.1±0.3	1.7	-10.3	133.4±0.9	2	124.3±0.4	22.3	-6.8
17	Elastik × Listopad	58.7±1.7	1.5	46.7±1.9	0.9	-20.4	6.2±0.3	11	5.2±0.3	-0.5	-16.1	137.1±0.8	1.7	128.0±0.4	9.7	-6.6
18	Elastik × Kupaysin	61.8±1.5	-0.2	47.3±1.8	0.3	-23.5	5.1±0.2	-2.4	4.7±0.1	-21	-7.8	111.6±0.4	-21.5	108.0±0.7	0.6	-3.2
19	Elastik × 108-RF	55.3±1.5	9.6	37.7±6.1	1	-8.3	5.8±0.4	0.2	5.1±0.5	-2	-12.1	132.6±2.3	29.4	101.2±0.8	-0.9	-23.7
20	Elastik × Farovon	50.4±1.6	1.2	33.3±1.2	0.3	-0.2	6.2±0.8	11	5.8±1.2	1.3	-6.5	114.5±0.2	-4.7	109.6±0.4	0.4	-4.3
21	Kupaysin × Elastik	71.5±2.3	0.6	55.8±1.2	1.4	-22	6.5±0.7	1.6	6.2±0.1	9	-4.6	126.6±0.6	16	113.0±0.3	1.6	-10.7
22	Kupaysin × Farovon	77.3±1.7	1.2	55.8±1.3	0.3	-27.8	6.1±0.2	0.3	5.9±0.2	1.3	-3.3	126.6±0.4	4.7	122.0±0.9	5.9	-3.4
23	Kupaysin × Listopad	81.8±1.9	1.6	30.6±1.6	0.2	-38.4	5.8±0.3	-0.7	3.5±0.1	-5	-5.2	118.0±0.3	-1.4	108.3±0.4	0.2	-8.2
24	Listopad × Kupaysin	86.8±5.6	2.1	55.7±1.2	2.1	-35.8	5.7±0.8	-1	3.6±0.3	-3	-1.8	112.4±0.3	-2.4	88.9±0.9	-8.8	-20.9
25	Listopad × 108-RF	64.4±1.8	3.4	51.3±1.5	1.3	-20.3	6.7±0.4	21	4.5±0.3	-5	-32.8	126.7±1.1	0.1	96.0±0.2	-5.2	-24.2
26	Listopad × Ishonch	68.2±1.8	6.6	47.9±1.1	-0.9	-29.8	6.7±0.8	4	5.5±0.4	-3	-17.9	130.0±0.4	-0.3	116.0±1.4	2.6	-10.8
27	Listopad × Farovon	77.7±1.2	6.2	62.2±1.9	1.9	-20	6.5±0.3	0.8	5.7±0.2	1	-12.3	116.0±0.9	-2.4	103.0±0.7	-1.7	-11.2
28	Listopad × Elastik	57.6±4.3	1.1	50.1±1.9	1.7	-11.5	5.7±0.2	1	5.1±0.9	-0.6	-10.5	114.6±0.2	-1.8	104.0±0.9	0.3	-9.3

cultivar with low indicators, negative over-dominance in four cultivars, and over-dominance in 19 cultivars (16 positives and three negatives). Positive and negative over-dominance were observed for the traits where the parental cultivars were close to each other. Under drought conditions, the cultivars Ishonch and Farovon showed higher seed cotton yield (58.7±1.7 and 57.6±1.1 g, respectively) compared with other cultivars, while relatively low yield came from cultivar Elastik (36.5±1.7 g.). In F_1 hybrids, the seed cotton yield ranged from 43.3±1.6 to 55.8±1.3 g. With water deficit conditions, the highest seed cotton yield showed in the F_1 hybrid Listopad × Farovon combination (62.2±1.9 g) and the lowest in the F_1 hybrid 108-RF × Kupaysin (41.8±1.3 g).

According to dominance coefficient (hp) indicators, the seed cotton yield in 22 cultivars of F_1 hybrids was inherited in the following states: Incomplete dominance in six cultivars with high indicators, incomplete dominance in three cultivars with low indicators, over-dominance in 13 combinations with six each positive and negative, and intermediate dominance in one cultivar where no dominance of the paternal or maternal form was observed. Mainly, the seed cotton yield decreased by 0.9%–30.8% in paternal cultivars and by 0.2%–57.7% in F_1 hybrids under water deficit conditions in the soil compared with the optimum water regime. The F_1 cross combinations, such as, Listopad × Farovon (62.2±1.9 g), Kupaysin × Elastik (55.8±1.2 g), and Listopad × Kupaysin, linked their resistance to water deficit conditions with high seed cotton yield and showed heterosis (55.7±1.2 g), which can serve as a base material in the selection of genotypes for drought tolerance.

Boll weight

Under drought conditions, cultivars Kupaysin and Ishonch gave the maximum boll weight (6.1±0.8 and 6.0±0.3 g, respectively), while the rest of the cultivars showed no significant difference (Table 3). In the F_1 hybrids, the highest boll weight resulted in F_1 hybrids Farovon × Kupaysin, 108-RF × Ishonch, and 108-RF × Farovon (6.9±0.7, 6.8±0.7, and 6.7±0.7 g, respectively), and smaller bolls appeared in F_1 hybrids 108-RF × Elastik and Elastik × Kupaysin hybrids (5.1±0.4 and 5.1±0.2 g, respectively).

With optimum water regime, the boll weight in 22 cultivars of F_1 hybrids was inherited in the following states: Incomplete dominance in three cultivars with larger bolls, incomplete dominance in three cultivars with smaller bolls, complete dominance in one cultivar with high indicators, complete dominance in one cultivar with low indicators, negative over-dominance in two cultivars, and positive over-dominance in 12 cultivars. Notably, the boll weight decreased in almost all the parental cotton cultivars and their hybrid under water deficit conditions.

With drought conditions, larger bolls occurred in the cultivar Ishonch (5.9±0.2 g), although smaller bolls in Farovon (5.1±0.2 g). In F_1 hybrids, the highest boll weight existed in F_1 hybrids 108-RF × Farovon, Farovon × Kupaysin, and Kupaysin × Elastik (6.5±0.3, 6.2±0.2, and 6.2±0.1 g, respectively), whereas the lowest boll weight recording in the cross combination 108-RF × Kupaysin (3.9±0.7 g).

With water scarcity conditions, the boll weight in 22 cultivars of F_1 hybrids was inherited in the following states: Negative over-dominance in nine cultivars, positive over-dominance in eight cultivars, incomplete dominance in three cultivars with small bolls, and complete dominance in one cultivar with large bolls. In the latest research, the coefficient of adaptability for boll weight in cotton genotypes ranged from 0% to -15.4% in parental cultivars and 3.0% to 38.0% in F_1 hybrids.

1000-seed weight

This study also checked the 1000-seed weight in parental cotton cultivars and their F_1 hybrids under different water regimes (Table 3). With optimum irrigation water supply, the cultivar Listopad gave the larger seeds and more 1000-seed weight (132.6±0.8 g), whereas cultivar 108-RF with a smaller seed and least 1000-weight (118.9±0.2 g). However, all other cultivars showed intermediate values.

In F1 hybrids, the 1000-seed weight ranged from 108.2±0.2 g (Farovon × 108-RF) to 139.5±0.2 g (108-RF × Farovon). In the F_1 hybrid Elastik × Listopad (137.1±0.8 g), the cultivars Elastik and Listopad sharply differed according to the trait index, with the dominance coefficient equal to 1.7 and the heredity a positive over-dominance. In the F_1 108-RF × Elastik, the parental cultivars 108-RF and Elastik were close to each other according to 1000-seed weight, and remarkably the thousand seed weight of these hybrids was higher than their parental cultivars. With optimum water conditions, the 1000-seed weight in 22 cultivars of F_1 hybrids was inherited in the following states: Incomplete dominance in three cultivars with low indicators, incomplete dominance in one cultivar with high indicators, positive over-dominance in eight cultivars, and negative over-dominance in 10 cultivars.

Under water deficit conditions, the 1000-seed weight ranged from 100.6±0.3 to 113.5±2.3 g in parental cultivars. In the F_1 hybrids, the highest 1000-seed weight took notice in F_1 hybrids Elastik × Listopad and 108-RF × Listopad (128.0±0.4 and 124.3±0.4 g, respectively). However, the lowest values acquired for the said trait came from F_1 hybrids Farovon × Listopad and Listopad × Kupaysin combinations (86.0±0.3 g and 88.9±0.9 g, respectively). Other F_1 hybrids showed no significant difference, and the trait index ranged from 89.0±0.1 to 122.0±0.9 g.

The 1000-seed weight in 22 cultivars of F_1 hybrids was inherited in the following states: Incomplete dominance in two cultivars with low indicators, incomplete dominance in five cultivars with high indicators, negative over-dominance in seven cultivars, and positive over-dominance in eight cultivars. In the cotton genotypes (cultivars and F_1 hybrids), the adaptability coefficient for 1000-seed weight ranged from -3.6% to -20.3% in parental cultivars and -3.2% to -29.8% in F_1 hybrids.

DISCUSSION

Generally, crop plants experience some degree of water stress during water deficit conditions (Parkash and Singh, 2020b). However, dehydration adversely affects the biochemical and physiological processes of crop plants (Yuan *et al.,* 2016). These changes in biochemical and physiological processes affect plant photosynthetic capacity and growth, resulting in reduced yields (Sharma *et al*., 2019). Leaf water content is another factor to determine drought tolerance in plants. Usually, plants with high water content are drought-tolerant plants (De-Brito *et al.,* 2011).

Seed size and weight are crucial traits determining cotton productivity, therefore, it is a dire need to study the inheritance of this trait and other yield-related traits. Past studies showed the cross-breeding of medium-sized seed cultivars with small-seeded cultivars, the inherited trait exhibit the state of incomplete dominance, and large-seeded cultivars with small and medium-seeded cultivars, the cultivars with large seeds have incomplete dominance over the cultivars with small seeds (Abdiev and Usmanov, 2016; Rizaeva *et al.,* 2018).

Chlorophyll content in the leaves of different crops, including cotton, varies under various factors (Abdurazakova *et al.,* 2020). The physiological and economic characteristics of the cotton plant change to a different extent under water deficit conditions. The present results on the decreased total water content and transpiration rate in plant leaves due to water stress also confirmed several past findings (Nabiev *et al.,* 2002; Norboeva and Kholliev, 2017; Nabiev, 2020). In the cotton plant, the drought conditions primarily lead to a violation of the water balance in the plant, a decrease in the transpiration process, and chlorophyll pigments (Kholliev *et al.,* 2015).

Compared with the optimal water regime, the seed cotton yield decreased by 0.9%–30.8% in the parental cotton cultivars and by 0.2%–57.7% in F_1 hybrids under water deficit conditions. This situation indicates that the seed cotton yield depends on water supply conditions, as well as, genotypic composition. The obtained results showed that the said trait was inherited differently in F_1 hybrids under different water regimes, where the variations in dominance coefficient depend on the water supply, as well as, the composition of the parental types of the F_1 hybrids.

Past studies revealed that the boll weight trait occurred relatively less variable versus other yield-related traits in cotton (Saydaliev *et al.,* 2005; Rizaeva *et al.,* 2018. Sanaev *et al.,* 2021). According to the latest results, boll weight in drought-resistant parental cultivars and their F_1 populations showed low genotypic sensitivity to water stress conditions. The study also confirmed both the genotypes and different water regimes significantly influence the 1000-seed weight of parental cotton cultivars and their hybrids. The physiological and economically valuable signs also expressed a good relationship.

CONCLUSIONS

Soil drought conditions disrupted the water exchange processes in the medium-staple cotton genotypes. Compared with the optimum water regime, the chlorophyll 'b' decreased by 3.0% to 46.7% in the parental cotton cultivars and 1.1% to 26.2% in their F_1 hybrids in the leaves under water deficit conditions. Chlorophyll 'b' is also inherited differently in F_1 hybrids under different water regimes. Compared with the optimal water regime, the total chlorophyll content decreased by 6.3% to 24.8% in the parental cultivars and 1.7% to

24.3% in the leaves of the F_1 hybrids under drought conditions. Carotenoid content increased by 8.5% to 39.1% in the parental cultivars and 2.1% to 44.2% in the F_1 hybrids under water deficit conditions, confirming that cotton genotypes acquire protection against water scarcity by enhanced carotenoid content in plant leaves. Study findings confirmed that the chlorophyll 'b' and total chlorophyll both depend on the irrigation water and the genotypic composition. The variations in dominance coefficient depend on water supply, as well as, the genetic make-up of the parental genotypes in the hybrids.

REFERENCES

Abdiev FR, Usmanov SA (2016). Using genetic statistical methods in the creation of cotton plant cultivars in Uzbekistan. *Int. J. Sci Res*. 6: 56-58.

Abdurazakova Z, Kurbanbaev ID, Yunuskhanov S, Abdishukirova S, Narimanov AA, Azimov A (2020). Chlorophyll content in the leaves of soybean plants in various phases of their development. *J. Crit. Rev.* 7(13): 173-176.

Ahmad MA, Murali PV, Panneerselvam R (2013). Drought stress-induced biochemical alterations in two cultivars of *Paspalum scrobiculatum* L. *Int. J. Curr. Sci*. 7: 80-96.

Anjum SA, Xie X, Wang L, Saleem MF, Man C, Lei W (2011). Morphological, physiological, and biochemical responses of plants to drought stress. *Afr J. Agric. Res.* 6(9): 2026-2032.

Beil GM, Atkins RE (1965). Inheritance of quantitative characters in grain sorghum. *Jowa State J. Sci.* 39(3): 345-358.

Beknazarov BO (2009). Plant Physiology. Tashkent. *Communicator Publishing House.* 536.

Bhattarai B, Singh S, West CP, Ritchie GL, Trostle CL (2020). Water depletion pattern and water use efficiency of forage sorghum, pearl millet, and corn under water limiting conditions. *Agric. Water Manag*. 238: 106206.

De-Brito GG, Sofiatti VM, de Lima MA, de-Carvalho LP, da-Silva FJL (2011). Physiological traits for drought phenotyping in cotton. *Acta Sci. Agron*. 33: 117-125.

Eberhart SA, Russel WA (1966). Stability parameters for comparing parameters. *Crop Sci.* 6: 36-40.

Ivanov AA, Silina AA, Tselniker YL (1950). On the rapid weighing method for determining transpiration in vivo. *Bot J*. 35(2): 171-185.

Jones E, Van-Vliet MT (2018). Drought impacts on river salinity in the southern US: Implications for water scarcity. *Sci. Total Environ.* 644: 844-853.

Kholliev AE, Norboeva UT, Zhabborov BI (2015). Influence of soil water deficit on some parameters of water exchange and drought resistance of cotton cultivars in the conditions of the Bukhara region. *Young Sci.* 10 (90): 483-485.

Kresovic B, Gajic BA, Tapanarova A, Dugalic G (2017). Yield and chemical composition of soybean seed under different irrigation regimes in the Vojvodina region. *Plant Soil Environ.* 63: 34-39.

Kushnirenko MD, Goncharova EA, Bondar EM (1970). Methods for studying water exchange and drought resistance of fruit plants. *Chisinau* pp. 79.

Lambers H, Oliveira RS (2019). Plant Water Relations, Plant Physiological Ecology. Springer International Publishing, *Cham.* 187-263.

Leila R (2007). Response of Tunisian autochthonous pearl millet to drought stress I used by polyethylene glycol 6000. *Afr. J. Biotechnol*. 6: 1102-1105.

Loggini B, Scartazza A, Brugnoli E, Navari–Izzo F (1999). Antioxidative defense system pigment composition and photosynthetic efficiency in two wheat cultivars subjected to drought. *Plant Physiol.* 119: 1091-1100.

Lu C, Zhang J (1999). Effects of water stress on photosystem II photochemistry and its thermostability in wheat plants. *J. Exp. Bot.* 50: 1199-1206.

Maleki A, Naderi R, Naseri A, Fathi A, Bahamin S, Maleki R (2013). Physiological performance of soybean cultivars under drought stress. *Bull. Environ. Pharmacol. Life Sci.* 2(6): 38-44.

Medvedev SS (2004). Plant Physiology*.* St. Petersburg: *Publishing House*. 336.

Mohawesh O (2016). Utilizing deficit irrigation to enhance growth performance and water-use efficiency of eggplant in arid environments. *J. Agric. Sci. Tech.* 18: 265-276.

Mohsenzadeh S, Malboobi MA, Razavi K, Farrahi-Ashtiani (2006). Physiological and molecular responses of *Aeluropus lagopoides* (Poaceae) to water stress. *Environ. Exp. Bot*. 56: 314-322.

Muhammad M, Chozin A, Lubis I, Junaedi A, Ehara H (2014). Some physiological character responses of rice under drought conditions in a paddy system. *J. Int. Soc. Augmen. Alt. Commun*. 20(1): 104-114.

Nabiev SM (2020). Morphophysiological and genetic features of cotton adaptation to soil moisture deficit. Abstract of the thesis. Doctor of Biology -Tashkent. 68.

Nabiev SM, Saakova NA, Ganiev UM (2002). Water stress and mechanisms of adaptation for cotton plants. The Third Inter. Cotton Genome Initiative Workshop, Nanjing, China 14: 100.

Norboeva UT, Kholliev AE (2017) Effects of salinity and moisture levels on physiological performance of cotton cultivars. *Khorezm Ma'mun Aca*. 3: 1-4.

Parkash V, Singh S (2020a). Potential of biochar application to mitigate salinity stress in eggplant. *Hort Sci.* 1: 1-10.

Parkash V, Singh S (2020b). A review on potential plant-based water stress indicators for vegetable crops. *Sustainability* 12: 3945.

Pazzagli PT, Weiner J, Liu F (2016). Effects of CO_2 elevation and irrigation regimes on leaf gas exchange, plant water relations, and water use efficiency of two tomato cultivars. *Agric. Water Manag*. 169: 26-33.

Porudad SS, Beg AS (2003). A suitable oil seed for dryland areas of Iran. In: Proceed. 7th Int. Conf. on the Development of Drylands. pp. 14-17.

Rahmani N (2006). Effect of irrigation and nitrogen application on the quantity and quality of medicinal plant Marigold (*Calendula Officinalis* L.). *J. Afr. Agric. Res.* 6(9): 2026-2032.

Reddy AR, Chaitanya KV, Vivekanandan MA (2004). Drought-induced responses of photosynthesis and antioxidant metabolism in higher plants. *J. Plant Physiol.* 161: 1189-1202.

Rejapova MM, Azimov AA, Khatamov MM, Dj. Kurbanbaev I, Matniyazova HX (2020). Indicators of abiotic and biotic stresses of local and foreign cotton (*G. hirsutum* L.). *Plant Cell Biotechnol. Mol. Biol*. 21(43&44): 8-15.

Rizaeva SM, Abdullaev AA, Ernazarova DQ, Amanov BKh, Mominov XA, Arslanov DM (2018). Indicators of some economic traits of lines created on the basis of interspecies hybridization. Integration of fundamental science and practice: Problems and prospects. Proceed. Republican Scientific and Practical Conf., Tashkent. pp. 22-24.

Sanaev NN, Gurbanova NG, Azimov AA, Norberdiev TN, Shavkiev SJ (2021). Inheritance of the plant shape trait of the varieties and introgressive lines of *G. hirsutum* L. in drought conditions. *Plant Cell Biotechnol. Mol. Biol*. 22(25-26): 122-129.

Saydaliev H, Ismailov N, Tojiboev A (2005). Heredity of pod weight. *Agric. Uzbekistan* 1:15.

Sharma S, Leskovar D, Crosby K (2019). Genotypic differences in leaf gas exchange and growth responses to deficit irrigation in reticulatus and inodorus melons (*Cucumis melo* L.). *Photosynthetica* 57: 237-247.

Shavkiev J, Azimov A, Nabiev S, KHamdullaev S, Amanov B, Matniyazova H, Kholikova M, Yuldashov U (2021). Comparative performance and genetic attributes of upland cotton genotypes for yield-related traits under optimal and deficit irrigation conditions. *SABRAO J. Breed. Genet.* 53(2): 157-171.

Shavkiev J, Nabiev N, Azimov A, Hamdullaev S, Amanov B, Matniyazova Kh, Nurmetov Kh (2020). Correlation coefficients between physiology, biochemistry, common economic traits, and yield of cotton cultivars under full and deficit irrigated conditions. *J. Crit. Rev*. 7(4): 131-136.

Singh M, Saini RK, Singh S, Sharma SP (2019). Potential of integrating biochar and deficit irrigation strategies for sustaining vegetable production in water-limited regions: A review. *Hort. Sci.* 54: 1872-1878.

Sumanta N, Imranul Haque C, Nishika J, Suprakash R (2014). Spectrophotometric analysis of chlorophylls and carotenoids from commonly grown fern species by using various extracting solvents. *Res. J. Chem. Sci*. 4(9): 63-69.

Tretyakov NN, Karnaukhova TV, Panichkin LA (1990). Workshop on plant physiology. *M. Agropromizdat.* 271.

Wakchaure G, Minhas P, Meena KK, Singh NP, Hegade PM, Sorty AM (2018). Growth, bulb yield, water productivity, and quality of onion (*Allium cepa* L.) as affected by deficit irrigation regimes and exogenous application of plant bioregulators. *Agric. Water Manag.* 199: 1-10.

Wijewardana C, Henry WB, Reddy KR (2017). Evaluation of drought tolerant maize germplasm to induced drought stress. *Miss Acad Sci*. 62: 316-329.

Wijewardana C, Reddy KR, Alsajri FA, Irby T, Krutz J, Golden B (2018). Quantifying soil moisture deficit effects on soybean yield and yield component distribution patterns. *Irrig. Sci.* 36: 241-255.

Wijewardana C, Reddy KR, Bellaloui N (2019). Soybean seed physiology, quality, and chemical composition under soil moisture stress. *J. Food Chem.* 278: 92-100.

Yuan XK, Yang Z, Li YX, Liu Q, Han W (2016). Effects of different levels of water stress on leaf photosynthetic characteristics and antioxidant enzyme activities of greenhouse tomato. *Photosynthetica* 54: 28-39.

Zareian J (2004). Effects of drought on the different stages of growth, and growth traits, cultivars of winter canola. MS Thesis Agronomy, Faculty of Agriculture. Islamic Azad University of Khorasgan. pp. 735-739.