

**Review Article**

**CORRELATION COEFFICIENTS BETWEEN PHYSIOLOGY, BIOCHEMISTRY, COMMON ECONOMIC TRAITS AND YIELD OF COTTON CULTIVARS UNDER FULL AND DEFICIT IRRIGATED CONDITIONS.**

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**Abstract**

Drought is a common abiotic stress that considerably limits crop production. The objective of this study is to explore the influence of water deficiency on the yield and physiologic-biochemical in upland cotton cultivars (*Gossypium hirsutum* L). Cotton cultivars, 'Ishonch', 'Navbakhor-2', 'C-6524' and 'Tashkent-6' were selected to study the relationships among their physiologic, biochemical and yield attributes during water deficiency. Deficit irrigation was designed by modifying the traditional watering protocol to reduce water use. Results indicate that cotton cultivars respond differently to water deficit stress. Water deficit significantly influenced plant valuable economic traits and yield in four cultivars. However, yield components such as the number of bolls per plant, seed number per boll, mass of boll per plant and productivity plant yield were significantly reduced only in C-6524 and Tashkent-6. The malondialdehyde decreased and total chlorophyll, chlorophyll "a" increased in 'Ishonch' and Navbakhor-2 under deficit irrigation conditions. The direct relationship between physiology, biochemistry, valuable economic traits, and yield may be a useful selection criterion for determining candidate parents for cotton drought tolerance breeding.

**Keywords:** *G. hirsutum* L, irrigation; cotton; drought tolerance; yield

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**INTRODUCTION**

As in many other regions of the world, water scarcity in Central Asia, and especially in Uzbekistan, remains one of the pressing problems [4]. Given the fact that the agriculture of our republic is based on irrigated agriculture, and the main crop is cotton, cotton varieties created in addition to high valuable economic indicators must be resistant to a number of adverse environmental factors. In this case, one of the important tasks is to study the drought tolerance of cotton varieties and to determine the dependence of the physiological and biochemical characteristics of the genotype on water deficiency. In the Decree of the President of the Republic of Uzbekistan dated February 7, 2017 PD-4947, research work on the creation and introduction of new breeding varieties of crops resistant to diseases and pests adapted to local soil, climatic and natural conditions is outlined as one of the urgent tasks [1]. For the development of cotton production in our republic, new cotton varieties being created, in addition to high yields and high fiber quality, must withstand abiotic stresses and endure drought.

Under the influence of abiotic stressful environmental factors such as salinization, high temperatures and water deficiency, the level of formation of reactive oxygen species in tissue cells (free radicals such as peroxide and superoxide) increases, which, in turn, leads to extensive functional disorders and deterioration photosynthesis in cells. This condition is called oxidative stress and is one of the main causes of disturbances in the plant organism as a result of disturbance of the external environmental environment [27]. A number of functional systems have been formed in the plant body that can withstand oxidative stress. In particular, various enzymes present in the cells of plant tissue reduce the level of formation of reactive oxygen species and, in turn, are involved in increasing the plant's resistance to adverse environmental conditions [26,28].

It is known that under the influence of environmentally stressful factors, such as drought, salinization, a sudden drop or increase in ambient temperature, an increase in the concentration of low molecular weight organic substances known under the general name osmoprotective substances in plant cells and these substances perform a protective function against adverse environmental factors [7]. In particular, osmoprotective substances such as proline, glycine betaine and mannitol have been found in plant tissue cells. Thus, by increasing the concentration of osmolytic substances, the stability of biologically important protein macromolecules and biological membranes is ensured, and these structures are protected from destruction, and the formation of free radicals such as reactive oxygen species accelerates the destruction of intermediate compounds. In genetic studies, it was suggested that the *imt 1* gene in tobacco and Arabidopsis plants is responsible for the synthesis of osmolytic compounds that protect against water deficiency, that is, in plants with the active *imt 1* gene, a high concentration is revealed in plants with this gene removed in drought conditions osmolytics and, in turn, a high level of resistance to stress factors [7].

Chlorophyll is one of the main components of chloroplast. Chlorophyll pigments "a" and "b" in chloroplasts are important in the process of photosynthesis, which leads to the growth and development of plants [28]. A decrease in photosynthesis is associated with the main components of the chloroplast, which directly limit the photosynthetic potential of the plant [17].

Quantitative changes in total chlorophyll, chlorophyll "a" and "b" were studied in plants of water deficit condition [9,13,15,10,12,]. In drought conditions, in sunflower varieties, a decrease in chlorophyll "a", chlorophyll "b" and a content of total chlorophyll are more pronounced compared to the optimal water regime [18]. In two varieties of olives, when grown under drought conditions, a decrease in the total

chlorophyll content from 29% to 42% is observed in comparison with the optimal water regime [11].

Cotton plants are characterized by a decrease in chlorophyll under drought conditions [19]. It was noted that a decrease in the level of chlorophyll under conditions of dry stress is associated with the degradation of chlorophyll during photooxidation [3, 10, 12]. A decrease in chlorophyll content in dry stress is a weakening of photosynthetic activity. In this case, swelling of the chloroplast membranes, violation of the lamellar vesicularity and accumulation of lipid droplets inside them were recorded [14].

Low concentrations of photosynthetic pigments and reduced photosynthetic potential limit plant productivity. The chlorophyll content in the leaf is one of the important parameters from a physiological point of view. The literature says that under conditions of water deficiency, loss of chlorophyll level can be caused by the destruction of mask cells in plants [26]. Carotenoids, the main component of chloroplast in plants, protect plants from photooxidation under stress [21]. A number of scientists in their experiments note that lack of water can have a negative effect on plant development, which will lead to a decrease in plant productivity by 50% [2, 21,23,25].

The problem of creating high-yielding cotton varieties requires a comprehensive study of the relationship between cotton growth, resistance to adverse environmental factors, and productivity. Because the physiological and biochemical processes in the body of a plant depend on the biological characteristics of the plant and environmental conditions. In other words, the probability of genetic inheritance is determined by the degree and severity of the main environmental factors.

## MATERIAL AND METHODS

### Experimental site, irrigation condition, and plant material

The experiment was conducted in the Tashkent region of Uzbekistan. The Tashkent region has a continental climate, according to the Koppen climate classification system. Hence, the region experiences cold winters and long, hot, and dry summers. The experimental station is located at 41.389°N and 69.465°E. The annual photoperiod (light/dark) is 16/8 h. Temperatures increase in April during cotton sowing season and decrease in late September before the harvesting period. Sunny days are between 175–185 d. Rainfall varies from 6 to 70 mm in the dry season for a period of 5–6 months. The crops require intensive irrigation throughout this vegetation period.

Cotton is irrigated according to the 1-2-1 (pre-flowering–flowering–boll opening) sequence with 900 m<sup>3</sup>/hm<sup>2</sup> of water applied before flowering, two applications of 1200 m<sup>3</sup>/hm<sup>2</sup> each during flowering, and 900 m<sup>3</sup>/hm<sup>2</sup> prior to boll opening phases. This is an optimal irrigation protocol is widely-used for cotton agriculture field in Uzbekistan. Soil moisture also contributes water during seed germination. A modified irrigation protocol was also developed for deficient irrigation conditions. It has a 0-1-0 sequence which limits water availability during pre-flowering, flowering and boll development stages and reduces the total irrigation requirement to 1200 m<sup>3</sup>/hm<sup>2</sup> of water. This study evaluates the response of selected cotton (*G.hirsutum*) cultivars, 'Ishonch', 'Navbakhor-2', 'C-6524' and 'Tashkent-6', to water deficiency under field conditions. 'Ishonch', 'Navbakhor-2', 'C-6524' and 'Tashkent-6', genotypes have an average fiber production (2.1–2.5 tons/hm<sup>2</sup>) but different tolerances to drought. Cotton cultivars were planted 10 cm apart in 60 cm wide by 50 m long furrows on 15 April, 2018 and three replicates. The number of three replicates were be 30 plants. The soil moisture content was 70% at optimal background and 42 % at water deficit background (Moisture Tester). Full(optimal) and deficit irrigation conditions were separated by a specified distance. Insecticides Bi-58 (BASF, Germany) and Hexachloran were applied to aphids and cotton bollworm, respectively. Seasonal application of fertilizer per annum

consisted of 250 kg/hm<sup>2</sup> nitrogen, 180 kg/hm<sup>2</sup> phosphorus and 115 kg/hm<sup>2</sup> potassium. Fertilizers were applied during tillage or before irrigation. Physiological, Biochemical and economic traits of selected cultivars were studied under water deficit conditions. Parameters such as Proline, Total chlorophyll, Chlorophyll a, Chlorophyll b, Carotenoid, Malondialdehyde, Catalase activity, Peroxide activity, Yield per plant, Mass per boll, Seeds per boll, Total bolls per plant were used to monitor stress conditions as compared to full irrigated conditions.

### Measurements of proline content

Free proline content was measured according to the method reported by Betes[5] Leaf samples (0.5 g) from each group were homogenized in 3% (w/v) sulfosalicylic acid, and the homogenates were filtered through a filter paper. Acid ninhydrin and glacial acetic acid were added, and the resulting mixture was heated to 100°C for 1 h in a water bath. The mixture was extracted with toluene, and the absorbance of the fraction with toluene that was aspirated from the liquid phase was read at 520 nm.

### Measurement of chlorophyll and carotenoid content

To determine chlorophyll a (Chl a), chlorophyll b (Chl b), and carotenoids levels, 3–4 discs (50 mg) were cut from the upper-most fully expanded leaves randomly selected from four plants. Discs were homogenized with 5 mL of Ethanol (95%). The absorbance of the pooled extracts was measured using a spectrophotometer (Agilent Cary 60 UV-Vis) at 470 nm, 644 nm, and 649 nm. Contents of Chl a, Chl b, and carotenoids in the extracts was determined using Nayek Sumanta, equations [22].

### Extraction and assay of antioxidant enzyme assay

For enzyme extractions, frozen root and leaf samples (0.5 g) were ground into a fine powder by using a mortar that was placed in an ice bath and a pestle that was pre-cooled with liquid nitrogen, and homogenized in 50 mM potassium phosphate buffer (pH 7.8) containing 1 mM ascorbate and 2% (w/v) polyvinylpyrrolidone. Homogenates were then centrifuged at 20,000x g for 30 min at 4°C.

Total CAT activity was measured according to the method reported by Beers and Sizer [6], with minor modifications. The reaction mixture (1.5 mL) consisted of 100 mM phosphate buffer (pH 7.0), 0.1 mM EDTA, 20 mM H<sub>2</sub>O<sub>2</sub>, and 50 mL enzyme extract. The reaction was initiated by the addition of the enzyme extract. The decrease in H<sub>2</sub>O<sub>2</sub> was monitored at 240 nm and was quantified by its molar extinction coefficient (36 M<sup>-1</sup>cm<sup>-1</sup>).

Peroxidase (POD) activity was measured by detecting the increase in absorbency at 460 nm as guaiacol was oxidized, according to the method of Chance and Maehly [8]. 50 µl enzyme extraction was added to the 2.85 ml of reaction mixture consisting of 1.85 ml 0.1M HAC-NaAC buffer (PH5.0), 0.25% guaiacol and 0.1ml 0.75% H<sub>2</sub>O<sub>2</sub>.

### Measurement of lipid peroxidation

Malondialdehyde (MDA) is one of the most important membrane lipid peroxidation metabolites. In order to understand the degree of cotton leaf membrane lipid peroxidation under drought condition, we measured MDA content as described by Heath and Packer [14]. In brief, 1 ml sample solution (supernate as above) was extracted in 2 ml of a solution containing 0.25% TBA (Thiobarbituric acid) and 10% TCA (Trichloroacetic acid). The extraction was heated in a water bath at 95°C for 30 min and then quickly cooled in icewater bath to room temperature. After centrifugation at 12,000 rpm for 15 min, the absorbance of the supernatant was measured at 532 nm and 600 nm (to eliminate the interference of non-specific impurities), respectively. The amount of MDA was calculated, based on adjusting absorbance and extinction coefficient 155 mM<sup>-1</sup> cm<sup>-1</sup>

### Measurement of yield components

Indicators of valuable economic characteristics were determined - the average yield(g), the mass per boll(g), the number of seeds per boll(quantity) and the number of total boll per plant (quantity) in thirty plants

### Statistical analysis

Data analysis was performed using StatView (SAS Institute Inc., Cary, NC, USA) with one-way ANOVA followed by a Fisher PLSD post hoc test ( $P < 0.05$  and  $P < 0.01$ ).

## RESULTS AND DISCUSSION

When we examined the proline content of cotton leaves in our experiment, we observed an increase in proline levels under conditions of optimal and water deficit stress. The proline quantity of the C-6524 variety is the highest (68.1  $\mu\text{g/g}$ ) and that of the Navbahor-2 variety is the lowest (39.4  $\mu\text{g/g}$ ) under conditions of optimal regime. The Ishonch variety the highest (75.2  $\mu\text{g/g}$ ) and the variety Tashkent-6 the lowest (69.4  $\mu\text{g/g}$ ) in conditions of water deficit stress (Table 1). The proline content in a drought-resistant plant compared with an unstable plant increases sharply in conditions of water deficit stress [29]. In our experiments under conditions of water deficiency, Ishonch and Navbahor-2 varieties synthesize proline in large quantities in comparison with C-6524 and Tashkent-6 varieties.

Variance analysis of the results shows that the differences in the levels of chlorophyll "a" and chlorophyll "b", total chlorophyll and carotenoids on the leaves of varieties Ishonch, Navbahor-2, C-6524 and Tashkent-6 are significant under conditions of different water irrigation (Table 1). At the same time, with optimal water regime condition, the highest index of total chlorophyll was recorded in cultivar C-6524 (2.3 mg/g) and the lowest index in cultivar Ishonch (2.0 mg/g). In case of water deficiency, the lowest index total chlorophyll was found in varieties Tashkent-6 (1.8 mg/g), and the highest index in reliability and varieties Navbahor-2 (2.2 and 2.2 mg/g). In case of water deficiency, the total chlorophyll in Ishonch and Navbahor-2 varieties increased compared to the optimal conditions, while in cotton varieties C-6524 and Tashkent-6 showed the opposite, i.e. they have decreased.

In optimal water regime, the highest chlorophyll a was recorded in the Navbahor-2 variety (1.57 mg/g) and the lowest in the Ishonch variety (1.34 mg/g). In condition of water deficiency, the lowest chlorophyll a values were found in varieties Tashkent-6 (1.31 mg/g) and the highest in varieties Ishonch and Navbahor-2 (1.61 and 1.69 mg/g). In condition of water deficit chlorophyll "a" quantities increased compared in Ishonch and Navbahor-2 varieties to the optimal water regime condition while for cotton varieties C-6524 and Tashkent-6 it decreased.

It was found that the content of chlorophyll "b" pigment in plant leaves decreases with water deficiency. Compared to the optimal water regime, the control background has the highest chlorophyll quantity "b" was registered in variety C-6524 (0.74 mg/g) and low in variety Navbahor-2 (0.54 mg/g). In case of water deficiency, the lowest chlorophyll "b" was in varieties Tashkent-6, (0.47 mg/g), and Ishonch cultivars were the highest (0.60 mg/g). In soil droughts, a decrease in the content of chlorophyll a and b may be due to inhibition of the oxidizing agent during photooxidation [10].

The experiments revealed an increase in the quantity of carotenoids in the leaves of plants compared with the control background. Under the optimal water regime, the largest number of carotenoids was registered in the Navbahor-2 variety 0.34 mg/g, and the lowest in Tashkent-6 (0.27 mg/g). In condition of water deficiency, the lowest carotenoids were in the Tashkent-6 variety, 0.31 mg/g, and the highest for Ishonch and Navbahor-2 and 0.40 mg/g varieties were 0.41 mg/g, respectively. Under conditions of water regime, it was found that carotenoids in cotton varieties Ishonch and Navbahor-2 were higher than in cotton varieties C-6524 and

Tashkent-6. A. K. Parida (2007) noted that the quantity of chlorophyll and carotenoids in cotton genotypes decreased in a low-water environment and increased the content of chlorophyll and carotenoids as a result of repeated irrigation.

According to a variance analysis of the results of our studies, the quantity of malonyl aldehyde on the leaves of cotton varieties Ishonch, Navbahor-2, C-6524 and Tashkent-6 significantly differed under different water regimes.

At the same time, the amount of malonylaldehyde in cotton with water deficit increased compared to optimal water regime conditions. The highest levels of malonyl dialdehyde in the control and experimental backgrounds were in varieties Tashkent-6 ( $202.3 \cdot 10^{-5}$  mmol/mg and  $359.0 \cdot 10^{-5}$  mmol/mg), and the lowest in varieties Navbahor-2 (148.8  $\cdot 10^{-5}$  mmol/mg and  $208.7 \cdot 10^{-5}$  mmol/mg). Under water deficit conditions, Malondialdehyde quantities in Ishonch and Navbahor-2 varieties was less than C-6524 and Tashkent-6 varieties (Table 1).

When the activity of catalase and peroxidase was studied experimentally, it was found that the enzyme activity decreased under conditions of water deficit regime compared to optimal water regime. At the same time, the highest activity of catalase in plant leaves is observed in Navbahor-2 ( $32.0 \pm 0.5$  and  $24.2 \pm 0.3$   $\mu\text{mol min}^{-1} / \text{mg protein}$ ), whereas in conditions of optimal water regime and water deficit the lowest is Tashkent-6. ( $23.4 \pm 0.4$  and  $15.8 \pm 0.2$   $\mu\text{mol min}^{-1} / \text{mg protein}$ ).

Under conditions of optimal water regime and water deficiency, peroxidase activity was the highest in terms in Tashkent-6 ( $180.3 \pm 2.9$  and  $121.5 \pm 0.5$   $\mu\text{mol min}^{-1} / \text{mg protein}$ ) variety, the lowest in Navbahor-2 ( $112.8 \pm 3.8$  and  $91.4 \pm 2.0$   $\mu\text{mol min}^{-1} / \text{mg protein}$ ) variety. On the experimental studied was catalase and peroxidase activities on the leaves of plants of cotton varieties C-6524 and Tashkent-6 sharply decreased under conditions of water deficit regime in relative to Navbahor-2 and Ishonch than conditions of optimal water regime.

In our experience, the yield index of plants in optimal water regime was close to each other in the varieties Ishonch, Navbahor-2, S-6524 and Tashkent-6. In condition of water water deficiency, the yield is higher for Ishonch and Navbahor-2 varieties, with average yields of 50.93 g and 50.03 g and Tashkent-6 and C-6524, respectively 34.77 and 35.46 g (Table 1). Yields index in Tashkent-6 and S-6524 varieties declined sharply due to water deficit compared to Ishonch and Navbahor-2 varieties.

Under conditions with optimal water regime, the weight of cotton in mass per boll was close to one for the varieties Ishonch, Navbahor-2, C-6524 and Tashkent-6. Under conditions of water deficiency, the lowest trait was observed in varieties C-6524 and Tashkent-6 (4.46 g and 4.60 g, respectively), and the highest rate was observed in varieties Navbahor-2 (5.53 g) (Table 1). It was established that water deficit on this basis had a stronger effect on C-6524 and Tashkent-6 varieties compared to Navbahor-2 and Ishonch.

Against the control and experience backgrounds, according to the number of seeds in per boll, the lowest indicator was found in the C-6524 variety (28.21 and 24.38). Under the optimal water regime, the highest index was 30.63 units in the variety Tashkent-6 and under the deficit water regime, the lowest index on average 27.08 units per in the Navbahor-2 variety (Table 1). Soil drought has led to a significant decrease in the number of seeds per boll in varieties C-6524 and Tashkent-6 compared with varieties Ishonch and Navbahor-2.

Under condition of optimal water regime, the number of boll on one plant was close to each other in the varieties Ishonch, Navbahor-2, C-6524 and Tashkent-6 (Table 1). The lowest indices of these traits in conditions of water shortage are in varieties C-6524 and Tashkent-6 (9.8 and 8.5), and the highest

were registered in varieties Ishonch and Navbakhor-2 (12.7 and 12.5) It was found that water deficit condition had a more negative effect on varieties C-6524 and Tashkent-6 on the number of boll per plant than on varieties Ishonch and Navbahor-2.

The experiments of a number of researchers (Rahman M., 2008[24], Abdel Hafiz, A. D., 2012[2]) in condition of water deficiency are also confirmed by our experience with the observed decrease in yield, mass in per boll and the number of boll per plant.

According to the results of our experiments, it was found that under conditions of water deficit in the varieties Ishonch, Navbakhor-2, C-6524 and Tashkent-6, the indicators of proline, carotenoids and malonyl dialdehyde are reliable compared to indicators condition of optimal water regime. It was found that according to chlorophyll b, plant productivity, the mass of cotton in per boll, the number of seeds in per boll and the number of bolls in one plant, the difference in reduction is significant.

In the experiment, we studied the relationship the level of significant differences in the indicators of water deficit and optimal water conditions.

In the case of optimal water regime, chlorophyll b with proline, Malonyldialdehyde with carotenoid and peroxidase are positively correlates. Malonylialdehyde with chlorophyll b and catalase activity, Peroxide with carotenoid and catalase and The total bolls per plant with mass per boll are negatively correlated(Table 2).

Moreover, under conditions of water deficiency, chlorophyll a with total chlorophyll, Chlorophyll b with proline, Carotenoid

with total chlorophyll and chlorophyll, The yield with the content of chlorophyll a and total chlorophyll, The catalase activity with the carotenoids and malondialdehyde and The number of of boll in per plant with the total chlorophyll, chlorophyll a and carotenoid are positively correlates. The carotenoids with catalase and peroxidase activity and the number of boll in per plant with the content of malondialdehyde were negatively correlated. (Table 2).

#### CONCLUSION

In this work, we studied physiologic, physiological-biochemical and valuable economical characteristic responses to water deficiency. Current findings demonstrated that Malondialdehyde decreasing and proline increasing prevent water loss which depends on genotype. The chlorophyll content tends to increase slightly when water stress applied in 'Ishonch' and 'Navbakhor-2'. Correlation between yield and most of valuable economic traits was uniform in 'Ishonch' and 'Navbakhor-2' varieties compared to 'Tashkent-6' and C-6245 varieties under conditions of water deficiency and optimal water regime cotton. Based on the analysis of physiological-biochemical and valuable economic characteristics of cotton varieties varieties Ishonch and Navbakhor-2 are more stable compared to cotton varieties C-6524 and Tashkent-6 This indicates that it is advisable to plant cotton varieties such as Ishonch and Navbakhor-2 in water deficit regions and in drought years. May use them as materials in tolerance of drought breeding.

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**Table 1 Indicators of physiological, biochemical and valuable economic traits characteristics of cotton varieties Ishonch, Navbahor-2, C-6524 and Tashkent-6 under conditions of full and water deficit irrigated.**

Cottonvarieties	'Ishonch'		'Navbakhor-2'		'C-6524'		'Tashkent-6'	
	full irrigated	deficit irrigated	full irrigated	deficit irrigated	full irrigated	deficit irrigated	full irrigated	deficit irrigated
Parameters of traits	Mean±SE	Mean±SE	Mean±SE	Mean±SE	Mean±SE	Mean±SE	Mean±SE	Mean±SE
Proline (µg/ g)	55.1±0.2 <sup>e</sup>	75.2±1.3 <sup>a</sup>	39.4±1.1 <sup>f</sup>	72.1±1.2 <sup>ab</sup>	68.1±1.2 <sup>c</sup>	72.4±1.2 <sup>b</sup>	62.5±0.3 <sup>d</sup>	69.4±1.1 <sup>bc</sup>
Total chlorophyll (mg/ g)	2.0±0.02 <sup>bc</sup>	2.2±0.05 <sup>ab</sup>	2.1±0.05 <sup>b</sup>	2.2±0.04 <sup>ab</sup>	2.3±0.06 <sup>a</sup>	1.9±0.05 <sup>c</sup>	2.1±0.02 <sup>b</sup>	1.8±0.02 <sup>d</sup>
Chlorophyll a (mg/ g)	1.34±0.02 <sup>f</sup>	1.61±0.01 <sup>b</sup>	1.57±0.04 <sup>c</sup>	1.69±0.02 <sup>a</sup>	1.52±0.04 <sup>d</sup>	1.39±0.03 <sup>e</sup>	1.39±0.01 <sup>e</sup>	1.31±0.02 <sup>s</sup>
Chlorophyll b (mg/ g)	0.69±0.01 <sup>b</sup>	0.60±0.04 <sup>c</sup>	0.54±0.01 <sup>d</sup>	0.52±0.02 <sup>e</sup>	0.74±0.03 <sup>a</sup>	0.54±0.03 <sup>d</sup>	0.70±0.01 <sup>b</sup>	0.47±0.03
Carotenoid (mg/ g)	0.33±0.02 <sup>cd</sup>	0.40±0.02 <sup>a</sup>	0.34±0.02 <sup>bc</sup>	0.41±0.01 <sup>a</sup>	0.32±0.01 <sup>de</sup>	0.35±0.02 <sup>b</sup>	0.27±0.02 <sup>f</sup>	0.31±0.01 <sup>e</sup>
Malondialdehyde (10 <sup>-5</sup> µmol / mg)	172.3±0.3 <sup>e</sup>	246.8±0.5 <sup>c</sup>	148.8±0.5 <sup>f</sup>	208.7±1.3 <sup>d</sup>	170.5±0.5 <sup>e</sup>	314.1±0.6 <sup>b</sup>	202.3±2.6 <sup>d</sup>	359.0±2.8 <sup>a</sup>
Catalase activity (µmol min / mg protein)	29.6±1.2 <sup>b</sup>	22.2±0.1 <sup>d</sup>	32.0±0.5 <sup>a</sup>	24.2±0.3 <sup>c</sup>	30.2±0.4 <sup>ab</sup>	21.8±0.2 <sup>d</sup>	23.4±0.4 <sup>cd</sup>	15.8±0.2 <sup>e</sup>
Peroxide activity (µmol min / mg protein)	128.2±3.4 <sup>b</sup>	103.9±2.0 <sup>e</sup>	112.8±3.8 <sup>d</sup>	91.4±2.0 <sup>f</sup>	133.3±2.4 <sup>b</sup>	92.6±1.8 <sup>f</sup>	180.3±2.9 <sup>a</sup>	121.5±0.5 <sup>c</sup>
Yield per plant (g)	70.73±4.66 <sup>a</sup>	50.93±4.34 <sup>b</sup>	71.02±5.47 <sup>a</sup>	50.03±5.36 <sup>b</sup>	78.42±5.44 <sup>a</sup>	35.46±2.64 <sup>c</sup>	78.04±6.45 <sup>a</sup>	34.77±4.05 <sup>c</sup>
Mass per boll(g)	5.70±0.14 <sup>ab</sup>	4.85±0.15 <sup>c</sup>	5.94±0.14 <sup>a</sup>	5.53±0.16 <sup>b</sup>	5.62±0.18 <sup>b</sup>	4.46±0.22 <sup>c</sup>	5.77±0.17 <sup>ab</sup>	4.60±0.14 <sup>c</sup>
Seeds per boll(quantity)	28.51±0.46 <sup>ab</sup>	26.82±0.79 <sup>bc</sup>	29.63±0.54 <sup>a</sup>	27.08±1.06 <sup>b</sup>	28.21±0.89 <sup>ab</sup>	24.38±1.06 <sup>d</sup>	30.63±0.89 <sup>a</sup>	26.31±0.74 <sup>d</sup>
Total bolls per plant(quantity)	15.8±1.3 <sup>ab</sup>	12.7±1.1 <sup>bc</sup>	14.3±1.0 <sup>ab</sup>	12.5±1.0 <sup>bc</sup>	16.3±1.0 <sup>ab</sup>	9.8±0.6 <sup>d</sup>	15.3±1.7 <sup>ab</sup>	8.5±1.0 <sup>d</sup>

The bars indicate standard errors and different lowercase letters show significant differences determined by one-way ANOVA, followed by a Fisher PLSD post hoc test (P<0.05).



**Table 2 Correlation coefficients between physiology, biochemistry, valuable economic traits and yield of cotton cultivars under full (lower diagonal) and deficit (upper diagonal) irrigated conditions(n = 30)**

	1	2	3	4	5	6	7	8	9	10	11	12
1		0.76	0.64	0.99**	0.76	-0.64	0.70	-0.50	0.71	0.16	0.12	0.80
2	0.52		0.98*	0.68	0.98*	-0.97*	0.82	-0.54	0.98*	0.76	0.62	1.00**
3	-0.36	0.60		0.56	0.98*	-0.99**	0.84	-0.59	0.96*	0.85	0.63	0.97*
4	0.97*	0.37	-0.52		0.68	-0.56	0.64	-0.45	0.63	0.05	0.05	0.73
5	-0.57	-0.043	0.44	-0.48		-0.99*	0.91*	-0.69	0.94	0.75	0.49	0.99*
6	0.68	-0.06	-0.67	0.66	-0.95*		0.89*	0.68	-0.93	-0.85	-0.55	-0.96*
7	-0.51	0.14	0.59	-0.47	0.98*	-0.97*		-0.92*	0.71	0.61	0.11	0.84
8	0.59	-0.002	-0.51	0.52	1.00**	0.97*	-0.99**		-0.40	-0.42	0.22	-0.58
9	0.82	0.72	0.04	0.68	0.71	0.64	-0.58	0.69		0.77	0.73	0.97*
10	-0.90	-0.42	0.40	-0.95*	0.19	-0.41	0.18	-0.24	-0.53		0.74	0.72
11	-0.22	-0.32	-0.08	-0.32	-0.67	0.47	-0.67	0.63	0.16	0.60		0.56
12	0.88	0.42	-0.39	0.94	-0.16	0.37	-0.14	0.20	0.50	-0.99**	-0.63	

**Note: Significant at P < 0.05\* and P < 0.01. Proline -1, Total chlorophyll -2, Chlorophyll a -3, Chlorophyll b-4, Carotenoid -5, Malondialdehyde -6, Catalase activity -7, Peroxide activity -8, Yield per plant -9, Massper boll -10, Seeds per boll-11, Total bolls per plant-12.**

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