International Journal of Agriculture Innovations and Research
Volume 3, Issue 4, ISSN (Online) 2319-1473
Manuscript Processing Details (dd/mm/yyyy) :
Received : 18/02/2015 | Accepted on : 24/02/2015 | Published : 28/02/2015

# The Effects of Moisture Stress on Seedling Growth Characteristics of Cotton Cultivars

**Mehdi Tamadon-Rastegar**
Phd student, Dept. of Agronomy,
Ramin Agriculture and Natural Resources
University of Khouzestan, Ahwaz, Iran
email: mehditamadonrastegar@gmail.com

**Hossain Gharineh**
Associate Professor, Department of
Agronomy, Ramin Agriculture and
Natural Resources University of
Khouzestan, Ahwaz, Iran

**Alireza Abdali Mashadi**
Associate Professor, Department of
Agronomy, Ramin Agriculture and
Natural Resources University of
Khouzestan, Ahwaz, Iran

**Mohammad Barzali**
Assistant Professor, Gorgan Research
Center

**Seyyed-Ata-Allah Siadat**
Associate Professor, Dept. of Agronomy, Ramin Agriculture and
Natural Resources University of Khouzestan, Ahwaz, Iran

***Abstract*: In order to evaluate the effects of moisture stress on seedling growth characteristics of cotton cultivars, a factorial green-house experiment with two factors in a completely randomized design with four replications was conducted during 2013-2014. In this project, the factors include cultivar with four cultivars of Siokra, Golestan, Armaghan and Sahel and factor of drought stress in three levels of no-drought stress, moderate drought stress and severe drought stress (with 75, 15 and 5% of field capacity). Studied characteristics were root length, dry and wet root weight, dry and wet stem weight, dry and wet leaf weight, dry and wet seedling total weight, plant height, total chlorophyll, leaf area index (LAI), catalase, superoxide dismutase, APX, Fv/Fm, stomatal conductance, and net photosynthesis. Results showed that the effect of drought stress was significant on total characteristics except for Fv/Fm and wet stem weight. The effect of treatment on surveyed cultivars was significant on total characteristics except for wet stem weight and activity of superoxide dismutase. The mutual effect of irrigation and cultivar was significant on dry and wet leaf weight, dry root weight, and dry seedling total weight, total chlorophyll, LAI, catalase, APX, stomatal conductance and net photosynthesis. Results showed that maximum dry root weight, dry and wet leaf weight, dry total weight and leaf area index was obtained from Sahel cultivar in no-stress; and maximum activity of catalase was obtained from Golestan cultivar in severe stress and maximum activity of APX was obtained from Siokra and Golestan cultivars in severe drought stress condition.**

*Keywords:* **Catalase, Drought Stress, Fv/Fm, Siokra Cultivar, Superoxide Dismutase.**

## 1. Introduction

Water deficit or drought is the most important environmental factor that has severe negative effects on agricultural performance all around the world (Selote, and Khana-Chopra, 2004). About 40% of fields on the earth are located in arid and semi-arid regions (Mendham, 1984). In these regions water is the main limitation and drought is considered as one of the factors inducing stress in plants (Sloan, 1990; Sierts, 1987). Based on the situation of climate of Iran which is located in arid and semi-arid regions and it has water crisis in these regions, choosing plants adapting to these conditions and also plants that could restore water and use if efficiently is highly important (Mohammadi, 2005). Moisture stress has an effect on many metabolic aspects and growth of plant (De, and Kar, 1995). From the perspective of crop management, germination fluctuations that are affected by environmental factors are ecologically very important (Baradford et al., 1992). Detecting the critical time and scheduling based on an accurate and detailed plan for the plant is the key to water maintenance and irrigation improvement and plant tolerance to water deficit in agriculture (Ngouajio et al., 2007). Cotton with scientific name of Gossypium Hirsutumm L. is considered as one of the plants that could tolerate drought and it is one of the industrial and strategic products of Golestan Province and it could tolerate water deficit provided that it has proper management of irrigation (Fathi Sa'adabadi & Navvabi, 2008). Enough water for normal growth and development of cotton is one of the main factors for growing this plant (Bieiorai et al., 2004). Water deficit reduces the plant growth, leaf area and ultimately photosynthesis (Fernandez et al., 1996). Growth and uniform distribution of the seedlings in the cotton field is one of the important factors in producing this plant. Rapid drying of the soil surface could have an effect on germination and growth of cotton seedlings (Toselli and Casenave, 2003). Growth and development of cotton root may be affected by water deficit; Allocation of dry matter to the roots and aerial parts is a changing process that could have an effect on productive capacity and drought tolerance of the plant; because in drought stress conditions usually the ratio of root to aerial part increases and this significantly helps the plant's survival (Mcmichal and Quisenberry, 1991). Severe water deficit during early stages of growth to mid-flowering period in the field results in slower growth, smaller plants, and fewer nodes of sympodial branches and less LAI (Burke and Omahony, 2001). In a study, the drought stress caused by increased environmental temperature had an effect on germination and power of the seedling and ultimately resulted in reduced cotton yield (Bielorani et al., 1983). Burke and Omahony (2001) believe that drought stress has an effect on germination and growth of cotton seedling. Study by Toselli and Casenave (2003) showed that cotton germination decreases under the influence of drought (-0.8 MPa). Fajri and Zeynali (2002) conducted an experiment on two cotton cultivars and they showed that increased drought stress results in decreased germination percentage, number of healthy seedlings, and germination speed. Generally, in arid and semi-arid regions, water deficit is one of the major factors limiting germination of seeds and growth of seedlings. In these regions, optimal conditions of soil are irregular and short; thus under such conditions, genotypes that could quickly germinate and establish could surely use these environmental conditions better and more. Due to this, in the current research the effects of moisture stress on seedling growth characteristics of cotton cultivars are evaluated under green-house condition with the aim of introducing the best cultivar under drought stress condition.

## 2. Materials and Methods

In order to evaluate the effects of moisture stress on seedling characteristics of cotton cultivars, a factorial green-house experiment with two factors in a completely randomized design with four replications was conducted during 2013-2014. In this project, the factors include cultivar with four cultivars of Siokra, Golestan, Armaghan and Sahel and factor of drought stress in three levels of no-drought stress, moderate drought stress and severe drought stress (with 75, 15 and 5% of field capacity). In this experiment, pots with height of 25cm and diameter of 5.5cm were used. After thinning, fertilization in the form of nutrient begun and pots were fed biweekly. Fertilization was conducted with 50ml of (N-P-K) 20-20-20 nutrient with 0.8% W/V (Hagh, 2003). Project implementation temperature was 27±3˚C. Before applying stress, water level at pots was 55 to 85% of field capacity in order to prevent any drought stress. This was done by daily weighing of the pots and irrigating them when necessary. Because of the growth difference of cultivars until reaching the specific stage and also because of different replications of cultivars, 35 to 45 days after cultivating the stress begun. The stress amount was based on irrigation amount of pots. Definitions of drought stress based on the relative soil water content (RSWC) are as follows:

RSWC = (current pot weight-dry pot weight-total plant wet weight) (pot weight after exiting the added water-dry pot weight)

And no-drought stress, moderate drought stress and severe drought stress were respectively defined in 15, 75 and 5% of RSWC (Hagh, 2003). After the second drought stress round, and after the emergence of first sign of wilting, 12 hours later they were irrigated at the field capacity; and after 48 hours, morphologic and physiologic evaluation was conducted. Measuring wet weight of the roots was conducted after breaking the pots and placing seedlings in the case filled with water. Then for evaporation of the extra water caused by washing the soil and measuring the root weight and aerial organs, seedlings were dried for one hour at room temperature in the lab, and then after conducting length and weight measurements of different organs, samples were put in the oven for 48 hours at 80˚C and then they were weighed. Surveying the amount of chlorophyll of total leaves was conducted with Jensen et al (1999) method. According to this method, for measuring chlorophyll concentration, 0.2g of leaf samples were extracted in acetone 80%. Then the achieved extract went through filter paper; and acetone was added until it reached volume of 25ml and complete extraction of chlorophyll happened. Absorbance was read at 645 and 663nm wavelengths, respectively, and by the use of the specific formula, the total chlorophyll concentration on fresh leaf was achieved based on mg/g (Lichtentaler, 1987).

$$\text{Total chlorophyll} = [20.2\ (D645) - 8.02\ (D663)] \times \frac{V}{1000W}$$

In order to determine the amount of antioxidants, sampling was conducted at monopodial growth stage (seedling stage). In order to prepare the enzyme extract for determining the activity of antioxidant enzymes, firstly, 0.5g of fresh leaf sample was washed with distilled water and dried and then 5ml of the solution containing 0.1 M potassium phosphate buffer (pH= 7.5) and 0.5 M EDTA were pulverized by the use of soft mortar and the achieved combination passed through cleaning cloth. Then this solution was poured in 1.5 ml tubes and was separated for 15 minutes by the use of refrigerated model centrifuge at 15000 rpm and 4˚C. The clear liquid inside the tube had the required enzyme extract. This solution was used in order to determine the amount of activity of antioxidants of SOD, CAT, and APX (Sairam et al., 2002). Sairam et al method (2001) was used for determining the amount of SOD. 13mMol methionine, 25Micromoles Nitroblue Tetrazolium, 6Micromoles EDTA 0.5 Molar, 1.5Ml 1M phosphate buffer solution (pH= 7.8), 6 Micromoles Riboflavin 1mM and 50mM sodium bicarbonate were used for preparing the reaction combination. Then 2.9ml of the achieved combination was poured into a sterile tube and immediately after adding 2Micromoles of Riboflavin and 0.1 ml enzyme extract, it was put under 2×15 watt fluorescent light bulb. In order to determine the enzyme activity of Superoxide dismutase, the combination went under spectroscopy by the use of spectrophotometer at a wavelength of 560 nm and at 23±2˚C. In order to determine the amount of CAT in the enzyme extract, Chance and Maehly method was used (Sairam et al., 2002). A combination of 15Microliter Hydrogen Peroxide and 0.1ml enzyme extract were extracted and by the use of 0.1M phosphate buffer solution (pH= 7) the solution volume reached to 3ml. Then the achieved combination went under spectroscopy at a wavelength of 240nm for 5 minutes, every 5 seconds. Extraction of APX was conducted by the use of 250mM phosphate buffer (pH= 7) and by the use of Nakano and Asada method (1981). 2ml of the reaction mixture for measurement of APX included 250mM phosphate buffer (pH= 7), 0.1mM EDTA, 0.5M Ascorbate and 2.1mM hydrogen peroxide. Measurement was conducted by the use of spectrophotometer at a wavelength of 290nm. For measuring Fv/Fm, 5 leaves were randomly chosen from each plot and Fv/Fm of each leaf was measured by the use of MINI-PAM photosynthesis yield analyzer (Genty et al., 1989). IRGA device (LCA4,ADC Bioscientific LTD Hoddoson UK) was used for measuring net photosynthesis in each LAI and stomatal conductance. All measurements were conducted during 09:00-11:00 AM in the light intensity of 1200-1400mMol photons per square meter. All measurements were conducted from the 3rd completely developed leaf, from the top of the plant. Leaf was put in a case for gas exchange while maintaining its perpendicular position to the sun for 1 minute and these factors were recorded. Combined analysis was conducted by the use of SAS 9.1 software. Mean treatments was compared by the use of Duncan's multiple range test at probability level of 5%.

## 3. Discussion & Conclusion

Variance analysis results indicated that the effect of drought stress and cultivar on the root length at level 1% was significant; but their mutual effect on root length was insignificant (see table I). In other words, the process of changes of this characteristic under the influence of irrigation treatments in different cultivars was the same. Mean comparison between different levels of drought stress showed that the highest root length was in no-stress conditions (14.45cm) and the lowest was in severe stress (8.55cm). Also among the surveyed cultivars, the highest root length belonged to Sahel cultivar (31.1cm) and the lowest belonged to Golestan cultivar (10.16cm) (see table III). In this regard, study by Zaifnejd (1997) in Sorghum indicated decreased root length caused by drought stress. Based on variance analysis results, the effect of drought stress on dry and wet root weight was significant at level 1% and the effect of cultivar on dry root weight was significant at level 1% and the mutual effect of cultivar and drought stress on dry root weight was significant at level 5% (see table I). Results achieved from mean comparison of different levels of drought stress indicate the significant decrease of dry and wet root weight by the increase of stress (see table III). In interaction between cultivar and drought stress the results showed that highest dry root weight belonged to Sahel cultivar at no-stress conditions (0.047 g per plant) (see table V). Results achieved from variance analysis indicated the significant effect of drought stress on dry stem weight at probability level of 1% (see table I). The highest dry stem weight was in no-stress condition (0.103g per plant) and the lowest was under severe stress (0.055g per plant) (see table III). Results of combined analysis of variance indicated the significant effect of drought stress treatment and cultivar at probability level of 1% on dry and wet leaf weight. Also the mutual effect of cultivar and drought stress on wet leaf weight and dry leaf weight was significant at level 5% and 1%, respectively (see table I). Generally by the increase of drought stress, dry and wet leaf weight decreases and the highest wet leaf weight (1.116) and dry leaf weight (0.144) happened in no-stress conditions (see table III). Mean comparison results showed that highest wet leaf weight was achieved in Sahel and Armaghan cultivars at no-stress conditions with amounts of 1.303 and 1.161g per plant, respectively. The highest dry leaf weight was also achieved in Sahel cultivar at no-stress conditions (0.176g per plant) (see table V). In this regard, surveying the physiological and morphological reactions of cotton to water stress showed that severe water deficit results in decreased leaf development (White and Raine, 2004). Variance analysis results showed that the main effect of cultivar on wet seedling weight was significant at level 1% and the main effect of drought stress on wet seedling weight was significant at level 5%. The main effect of cultivar and drought stress and their mutual effect were significant on dry seedling weight at level 1% (see table I). Results achieved from mean comparison showed that the highest total wet weight (1.467g per plant) and the lowest total dry weight (0.284g per plant) were achieved at no-stress conditions and the lowest total wet weight (0.86g per plant), and the total dry weight (0.148g per plant) were achieved at severe stress condition (see table III). Mean comparison between cultivars showed that the highest wet weight (1.255g per plant) and total dry weight (0.239g per plant) were achieved in Sahel cultivar (see table III). Results achieved from mean comparison of mutual effect showed that highest total dry weight was achieved in Sahel cultivar at no-stress condition (0.337g per plant) and the lowest was achieved in Golestan cultivar at severe stress condition (0.141g per plant). In general, in this survey, a significant decrease in dry weight of aerial organs (leaf, stem and total plant) happens because of the increasing severe drought stress; and this is consistent with research results of EdalatiFard et al (2006) about cotton; they stated that perhaps decreased weight is due to the water shortage and stomatal closure and ultimately due to the decreased photosynthesis in the plant. This is consistent with research results on Zaifnejd (1997) in Sorghum. Variance analysis results showed that the effect of drought stress treatments and surveyed cultivars was significant on plant height at probability level of 1% (see table I). In these regard, EdalatiFard et al (2006) reported similar results; whereas the mutual effects of treatments were insignificant. In other words, the process of changes in this characteristic under the influence of irrigation treatments in different cultivars was the same. Mean comparison between different levels of drought stress showed that the highest plant height was achieved at no-stress condition (17.83cm) and the lowest was achieved at severe stress condition (10.54cm). In mean comparison between surveyed cultivars, the highest plant height was achieved in Sahel cultivar and there was no significant difference between other cultivars in terms of plant height in green-house conditions (see table III). Studies showed that Water deficit results in slow growth, decreased nodes and decreased plant heights (Burke and Omahony, 2001). On the other hand, it seems that different plant height among different cultivars could be related to their capability to use the environmental conditions (Tabatabaei and Shakeri, 2011). Variance analysis results showed that the effect of drought stress on enzymes of CAT, APX, and superoxide dismutase was significant at probability level of 1% (see table II). By the increase of drought stress the activity of enzymes of CAT, APX, and superoxide dismutase significantly increases and reaches its highest amount in the irrigation at 5% of filed capacity (see table IV). Also the main effect of cultivar and the mutual effect of cultivar and drought stress were significant on enzyme activities of CAT, APX, and superoxide dismutase at probability level of 1% (see table II). Mean comparison results indicated that the highest activity of APX enzyme was achieved in Siokra cultivar at no-stress condition (0.97mg protein per minute) and Golestan cultivar (0.98mg protein per minute); and the lowest activity of this enzyme was achieved in Sahel cultivar at no-stress condition (0.41mg protein per minute). Also the highest enzyme activity of CAT was achieved in Golestan cultivar at no-stress condition (214.75mg protein per minute) and the lowest activity was achieved in Armaghan cultivar at no-stress condition (61mg protein per minute) (see table V). In fact the activity of antioxidant enzymes has an important role in clearing of reactive oxygen species; thus they increase the drought tolerance (Alscher et al., 2002). Enzyme activity of CAT, directly converts hydrogen peroxide to water and oxygen (Gasper et al., 2002); thus enzyme synthesis of CAT is an adaptive response to oxidative stress (Mitter, 2002). Along with this, under drought stress the increased activity of CAT enzyme in corn (Jiang and Zhang, 2002), and wheat (Luna, 2004) and increased activity of APX in cotton (Ratnayaka, 2003) and rice (Sharma and Dubey, 2005) and increased activity of superoxide dismutase in wheat (Tian, 2007) have been reported. Results achieved from this experiment indicated that the main effect of cultivar and drought stress at probability level of 1% and their mutual effect at probability level of 5% were significant on total chlorophyll amount (see table II). Mean comparison of mutual effect of cultivar and drought stress indicated that the highest total chlorophyll amount was achieved in Golestan cultivar at no-stress conditions (0.25mg per g fresh leaf) and the lowest was achieved in Armaghan cultivar at severe stress condition (1.338mg per g fresh leaf)and Sahel cultivar (1.415ml per g fresh leaf) (see table V). Generally, by increasing the tension the total chlorophyll amount decreases. In order to explain this it could be said that water shortage results in damaging pigments and plastids and thus it results in decreased chlorophyll content of the leaf (Ashraf, 2001). Results achieved from the current experiment did not show any significant difference for Fv/Fm among drought stress treatments. This is consistent with research results of Fathi (2010) about safflower and Shangguan (2000) about wheat; bt there was a significant difference among different cultivars in terms of Fv/Fm at probability level of 1% (see table II). The highest Fv/Fm was achieved in Armaghan cultivar and the lowest was achieved in Siokra and Golestan cultivars. Variance analysis results showed that the main effect of cultivar and drought stress and their mutual effect at probability level of 1% were significant on LAI (see table II). Mean comparison results between different levels of drought stress showed that by increasing the tress the LAI decreases (see table IV). Also in mean comparison of mutual effect of drought stress and cultivar, the highest LAI was achieved in Sahel cultivar at no-stress condition (0.175) and in Siokra cultivar (0.17) and the lowest HI was achieved in Armaghan cultivar (0.082) and Golestan cultivar (0.084) at severe stress condition (see table V). It seems that by beginning of water stress, inhibition of cell growth results in decreased leaf development and less leaf are results in less water absorption from the soil and ultimately less transpiration. Water shortage may also limit the expansion of plant's canopy through affecting on number, size and fall of leaf. Limited leaf area is the first line of defense for coping with drought (Sa'adabadi and Navvabi, 2008). Results achieved from this experiment showed that the effect of drought stress and cultivar and their mutual effect on stomatal conductance were significant at level 1% (see table II). The highest stomatal conductance was achieved at no-stress and the lowest was achieved at severe stress conditions (see table IV). Also in mean comparison of mutual effect of cultivar and drought stress, the highest stomatal conductance was achieved in Siokra cultivar at no-stress condition (see table V). Variance analysis results indicated the significant effect of drought stress, cultivar and their mutual effect at probability level of 1% (see table II). In mean comparison of main effect of stress and increased stress, a significant decrease of net photosynthesis was observed (see table IV). In mean comparison of mutual effect of drought stress and cultivar, the highest rate of net photosynthesis was achieved in Golestan cultivar at no-stress conditions. The lowest rate of net photosynthesis was achieved in Sahel and Golestan cultivars at severe stress conditions (see table V). Generally water stress through decreased leaf area, stomatal closure, decreased stomatal conductance, decreased water intake of chloroplasts and other parts of protoplasm (which decrease the photosynthetic efficiency), decreased protein synthesis and chlorophyll result in decreased photosynthesis. Water stress could directly have an effect on biochemical processes of photosynthesis and could indirectly decrease the entry of carbon dioxides to stomatal that is closed because of water shortage. Also transfer of photosynthetic materials is affected by water stress and results in leaves saturation with these materials that may limit photosynthesis. It is obvious that by limited photosynthetic products during water shortage conditions the plant confronts deficiency (Hekmat Shoar, 1993). Cox and Jolliff (1987) observed that LAI and net assimilation rate in soybean decrease under the influence of lack of moisture.

Table I. Variance Analysis of Effect of Drought Stress on Seedling Characteristics of Cotton Cultivars.

| Sources of variation | Df | Mean squares | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | root length | wet rootweight | dry root weight | wet stem weight | dry stem weight | wet leaf weight | dry leaf weight | wet seedling total weight | dry seedling total weight | plant height |
| stress | 2 | 141.54** | 0.0116** | 0.003** | 0.0559ns | 0.0093** | 0.777** | 0.0153** | 1.487** | 0.0756** | 214.68** |
| cultivar | 3 | 20.32** | 0.0006ns | 0.00026** | 0.0034ns | 0.0004ns | 0.046** | 0.0016** | 0.088* | 0.0057** | 18.72** |
| stress×cultivar | 6 | 1.52ns | 0.0001ns | 0.00003* | 0.0021ns | 0.00007ns | 0.0239* | 0.0005** | 0.039ns | 0.0009** | 2.49ns |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| error | 36 | 1.04 | 0.0003 | 0.00001 | 0.025 | 0.00014 | 0.0095 | 0.00006 | 0.026 | 0.00027 | 4.85 |
| coefficient of variation | | 9.03 | 24.14 | 15.71 | 22.92 | 15.59 | 10.96 | 7.33 | 14.07 | 7.92 | 15.3 |

$^{ns}$, $^{*}$, $^{**}$ are insignificant and significant respectively, at levels 5 and 1%.

Table II. Variance Analysis of Effect of Drought Stress on Biochemical Characteristics of Cotton Cultivars.

| Sources ofvariation | Df | Mean squares | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | LAI | Totalchlorophyll | CAT | Superoxidedismutase | APX | Fv/Fm | Stomatalconductance | Netphotosynthesis |
| Stress | 2 | 0.0202$^{**}$ | 20.742$^{**}$ | 69789.77$^{**}$ | 7.315$^{**}$ | 0.45226$^{**}$ | 0.0000008$^{ns}$ | 9544.77$^{**}$ | 348.84$^{**}$ |
| Cultivar | 3 | 0.00095$^{**}$ | 0.725$^{**}$ | 827.33$^{**}$ | 0.289$^{ns}$ | 0.15214$^{**}$ | 0.0000104$^{**}$ | 506.14$^{**}$ | 7.365$^{**}$ |
| Stress×Cultivar | 6 | 0.000068$^{**}$ | 0.725$^{*}$ | 98.668$^{**}$ | 0.169$^{ns}$ | 0.00287$^{**}$ | 0.0000004$^{ns}$ | 19.83$^{**}$ | 0.2909$^{**}$ |
| Error | 36 | 0.0000847 | 0.067 | 0.2222 | 0.287 | 0.00084 | 0.00000026 | 4.47 | 0.0023 |
| Coefficient of variation | | 2.26 | 6.13 | 0.369 | 10.84 | 1.27 | 0.06 | 2.57 | 0.46 |

$^{ns}$, $^{*}$, $^{**}$ are insignificant and significant respectively, at levels 5 and 1%.

Table III. Mean Comparison of Main Effects of Drought Stress and Cultivar by the Use of Duncan's Method at Level 5% on Surveyed Characteristics of Cotton in Green-House Conditions.

| | Root length(cm) | Wet root weight (g per plant) | Dry root weight (g per plant) | Dry stem weight (g per plant) | Wet leaf weight (g per)plant | Dry leaf weight (g per plant) | Total wet weight (g per plant) | Total dry weight (g per plant) | Plant height (cm) |
|---|---|---|---|---|---|---|---|---|---|
| Stress levels | | | | | | | | | |
| No-stress | 14.45a | 0.066a | 0.037a | 0.103a | 1.116a | 0.144a | 1.467a | 0.284a | 17.83a |
| Moderate stress | 10.84b | 0.025b | 0.017b | 0.074b | 0.188b | 0.105b | 1.112b | 0.196b | 14.83b |
| Severe stress | 8.55c | 0.015c | 0.011c | 0.055c | 0.676c | 0.083c | 0.86c | 0.148c | 10.54c |
| Cultivars | | | | | | | | | |
| Armaghan | 11.3b | 0.037a | 0.022ab | 0.076a | 0.916ab | 0.112b | 1.174ab | 0.211b | 13.69b |
| Sahel | 13.1a | 0.045a | 0.028a | 0.085a | 0.968a | 0.126a | 1.255a | 0.239a | 16.25a |
| Siokra | 10.57bc | 0.032a | 0.019b | 0.075a | 0.843b | 0.103c | 1.086b | 0.197c | 14.04b |
| Golestan | 10.16c | 0.028a | 0.017b | 0.072a | 0.838b | 0.101c | 1.071b | 0.19c | 13.61b |

At each column, similar words indicate lack of significant difference among mean treatments.

Table IV. Mean Comparison of Main Effects of Drought Stress and Cultivar by the Use of Duncan's Method at robability Level 5% on Biochemical Characteristics of Cotton in Green-House Conditions.

| | LAI | Total chlorophyll (Mg perg fresh leaf) | CAT (Mg protein per minute) | Superoxide dismutase (Mg protein per minute) | APX (Mg protein per minute) | Fv/Fm | Stomatal conductance(mmolm$^{-2}$s$^{-1}$) | Net photosynthesis (µmolco2 m-2 s-1) |
|---|---|---|---|---|---|---|---|---|
| Stress levels | | | | | | | | |
| No-stress | 0.164a | 3.801a | 64.44c | 4.19c | 0.555c | 0.8384a | 107.56a | 15.41a |
| Moderate stress | 0.13b | 2.95b | 122.12b | 5.11b | 0.723b | 0.8387a | 80.5b | 9.09b |
| Severe stress | 0.093c | 1.547c | 196.18a | 5.51a | 0.891a | 0.8388a | 58.81 | 6.29c |
| Cultivars | | | | | | | | |
| Armaghan | 0.121c | 2.53b | 119.58c | 5.11a | 0.72c | 0.8397a | 74.33d | 9.94c |
| Sahel | 0.138a | 2.59b | 125.75b | 5.03a | 0.56d | 0.8391b | 80.25c | 9.35d |
| Siokra | 0.135b | 2.905a | 125.75b | 4.83a | 0.79b | 0.8381c | 89.42a | 10.65b |
| Golestan | 0.12c | 3.04a | 139.25a | 4.79a | 0.81a | 0.8378c | 80.25b | 11.13a |

At each column, similar words indicate lack of significant difference among mean treatments.

Table V. Mean Comparison of Main Effects of Drought Stress and Cultivar by the Use of Duncan's Method atrobability Level 5% on Surveyed Characteristics of Cotton in Green-House Conditions.

| Stress levels | Cultivar | Dry root weight (g per plant) | Wet leaf weight (g per plant) | Dry leaf weight (g per plant) | Total dry weight (g per plant) | LAI | Total chlorophyll (Mg per g fresh leaf) | CAT (Mg protein per minute) | APX (Mg protein per minute) | Stomatal conductance (mmolm-2s-1) | Net photosynthesis (µmol co2 m-2 s-1) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No-stress | Armaghan | 0.039ab | 1.164a | 0.148b | 0.284b | 0.1558b | 3.612c | 61j | 0.58f | 102.25d | 15.14c |
| No-stress | Sahel | 0.047a | 1.303a | 0.176a | 0.337a | 0.1749a | 3.468c | 62.25i | 0.41h | 106c | 14.84d |
| No-stress | Siokra | 0.033bc | 1.01b | 0.127c | 0.261c | 0.1696a | 3.877b | 62.75i | 0.6ef | 112.75a | 15.51b |
| No-stress | Golestan | 0.03bc | 0.988b | 0.125c | 0.253c | 0.1544b | 4.25a | 71.75h | 0.63e | 109.25b | 16.16a |
| Moderate stress | Armaghan | 0.018de | 0.962b | 0.108de | 0.202e | 0.1252d | 2.639f | 116.5g | 0.73d | 70.5h | 8.69g |
| Moderate stress | Sahel | 0.024cd | 0.879b | 0.114cd | 0.223d | 0.1394c | 2.887e | 120.75e | 0.53g | 80.25g | 7.83h |
| Moderate stress | Siokra | 0.014de | 0.852bc | 0.099ef | 0.184f | 0.1307cd | 3.113de | 120f | 0.8c | 87.75e | 9.74f |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Moderate stress | Golestan | 0.014de | 0.869bc | 0.097ef | 0.176f | 0.1247d | 3.162d | 131.25d | 0.82bc | 83.5f | 10.12e |
| Severe stress | Armaghan | 0.011e | 0.659d | 0.081g | 0.147cd | 0.0818f | 1.338h | 181.25c | 0.85b | 50.25k | 5.99k |
| Severe stress | Sahel | 0.013de | 0.721cd | 0.088fg | 0.159g | 0.0989e | 1.415h | 194.25b | 0.75d | 54.5j | 5.38l |
| Severe stress | Siokra | 0.01e | 0.668d | 0.082g | 0.146gh | 0.105e | 1.724g | 194.5b | 0.97a | 67.75h | 6.7l |
| Severe stress | Golestan | 0.008e | 0.657d | 0.081g | 0.141h | 0.0838f | 1.709g | 214.75a | 0.98a | 62.75l | 7.12l |

At each column, similar words indicate lack of significant difference among mean treatments.

## REFERENCES


[1] Alscher, R.G. Erturk, N. and Heath, L.S. (2002). Role of superoxide dismutases in controlling oxidative stress in plants, J. Exp. Bot., 53(372):1331-1341

[2] Ashraf , M. Shabaz, M. Mahmood, S. and Rasul, E. (2001). Relationship between growth and photo synthetic characteristics in pearl millet(*Pennisetum glaucum*) under limited water deficit conditions with enhanced nitrogen supplies, Belgian J. Bot. 134: 131-144.

[3] Baradford, K. J. Dahal, P. and Ni, B. R. (1992). Quantitative models describing germination responses to temperature water potential and growth regulators. Fourth, International workshop biology. 1: 239:248.

[4] Bieloriya, H. Matell, A. and Moresht, S. 1983. Water relation of cotton in water deficits and plant growth Vol. VII. Kozwassei. T.T. pp. 49057. New York academic press, U.S.A.

[5] Burke, J.J. and Omahony, J. (2001). Protective role in acquired term tolerance of developmentally regulated heat shock proteins in cotton seeds. *Journal of Cotton Science*. 2, 147-183

[6] Cox, W.J. and Jolliff, G.D. (1987). Water reations of sunflower and soybean under irrigated and dryland conditions. *Crop Sci*, 27:553-557.

[7] De, R. and Kar, R. K. (1995). Seed germination and seedling growth of mung bean (Vigna radiate) under water stress induced by PEG 6000. Seed Sci and Techno. 23: 301- 308.

[8] Edalati Fard, L. Galeshi,S. Soltani,A. Akram Ghaderi, F "Role of morphologic characteristics in genotypes of cotton", Agricultural sciences and natural resources, 2006, 13(2): 81-93. [in Persian]

[9] Fajri, A. Zeynali, "Effect of salinity and drought on germination and growth of seedlings of two cotton cultivars", Journal of seed and plant, 2002, 18(4): pp. 506-509. [in Persian]

[10] Fathi Amiz Khiz, K, "Effect of soil and foliar application of iron on morphological and physiological characteristics of one cultivar of spring safflower under water deficit stress, Master thesis, Shahed University, 2010. [in Persian]

[11] FathiSa'adabadi, M. Navvabi, F, "Effect of drought stress on performance and its components in 4 genotypes of cotton in Darab region", Iran crop sciences, 2008, 2: pp. 110-124. [in Persian]

[12] Fernandez, C. J. Mcinnes, K. J. and Cothern, T. (1996). Water status and leaf area production in water and nitrogen stressed cotton. Crop Science. 36: 1224-1233.

[13] Gasper, T.H., Penel, C., Hagega, D. and Greppin, H. ( 1991). Peroxidases in plant growth, differentiation and development process. In: LobarzewskiJ.,Greppin H., Penel C. and Gasper T.H. (eds), Biochemical, Molecular and Physiological Aspects of Plant Peroxidases. University de Geneve, Switzerland. pp. 249–280.

[14] Genty, B. Briantais, Y. M. and Baker, N. R. (1989). The relationship between the quantum yield of photosynthetic electron transport and quenching of chlorophyll fluorescence. Biochemi Biophys. Acta. 990, 87-92.

[15] Hekmat Shoar,H, "Physiology of plants in hard conditions", Tabriz: Niknam publications, 1993, p. 251. [in Persian]

[16] Hugh J. E. (2003). A precise gravimetric method for simulating drought stress in pot experiments. Crop Science.,43, 868-1873

[17] Jiang,M. and Zhang, J. ( 2002). Waterstress - induced abscisicacid accumulation triggers the increased generation of reactive oxygen species and upregulates the activities of antioxidant enzymes in maize leaves, J Exp Bot; 53:2401 - 10.

[18] Johnson, I.R.Melkonian, J.J.Thornley, J.H.M. and Riha, S.J. ( 1991). Amodel of water flow through plants incorporating shoot/root message control of stomatal conductance. *Plant Cell Environ*. 14: 531-544.

[19] Lichtenthaler, H.K. (1987).Chlorophylls and carotenoids:Pigments of photosynthetic biomembranes, Methods Enzymol.148: 350-382.

[20] Luna, C.M.Pastori, G.M.Driscoll, S.Groten, K.Bernard, S. and Foyer, C.H. (2004). Drought controls on H2O2 accumulation, catalase(CAT) activity and CAT gene expression in wheat. J Exp Bot; 56:417 - 23.

[21] Mcmichal, B. L. and Quisenberry, J. E. (1991). Genetic variation for root shoot relationship among cotton germplasm. Journal of Experimental Botany. 36: 51-59.

[22] Mendham, N.J.Russel, J. and Buzza, G.C. ( 1984). The contribution of seed survival to yield in new Australian cultivars of oil seed rape (*Brassicanapus L.*)J. Agri. Sci. Camb. 103:303-316.

[23] Mittler, R. ( 2002). Oxidative stress, antioxidants and stress tolerance. Trends Plant Sci. 7:405–409.

[24] Mohammadi, G.Javanshir, A.Khooie, F.R.Mohammadi, S.A. and Salmasi, S.Z. (2005). Critical period of weed interference in chickpea. Weed Res. 45(1):57-63.

[25] Ngouajio, M. Wang, G. and Goldy, R. (2007). Withholding of drip irrigation between transplanting and flowering increases the yield of field-grown tomato under plastic mulch. Agricultural water management, 87: 285-291

[26] Ratnayaka, H.H.Molin, W.T. and Sterling, T.M. (2003). Physiological and antioxidant responses of cotton and spurred and a under interference and mild drought. J Exp Bot; 54:2293 - 305. .

[27] Sairam, R.K. Veerabhadra Rao, K. and Srivastava, G.C. (2002). Differential response of wheat genotypes to long term salinity stress in relation to oxidative stress, antioxidant activity and osmolyte concentration. *Plant Science*. 163: 1037-1046.

[28] Sairam, R.K. and Srivastava, G.C. ( 2001). Water stress tolerance of wheat Triticumaestivum *L.*: Variation in hydrogen peroxide accumulation and antioxidant activiy in tolerant and susceptible genotype. *Journal of Agronomy and Crop Science*. 186: 63-70.

[29] Selote, D.S. and Khana-Chopra, R. (2004). Drought-induced spikelets terility is associated with an inefficient antioxidant defence in rice plants. *Physiol Plant*. 121:462–467

[30] Shangguan, Z. Shao, M. and Dyckmans, J. (2000). Effects of nitrogen nutrition and water deficit onnet photosynthetic rate and chlorophyll fluorescence in winter wheat. J. *Plant Physiol*. 156: 45-51.

[31] Sharma, P. and Dubey, R.S. (2005). Drought induces oxidative stress and enhances the activities of antioxidant enzymes in growing rice seedlings. Plant Growth Regu; 46:209 - 21.

[32] Sierts, H.P. Geisler,G.Leon, J. and Dipenbrock, W. ( 1987). Stability of yield component for winter oilseed rape(*Brassica napus L.*) J. Agron Crop Sci:158:107-113.

[33] Sloan, R. J. Patterson, R. P. and Carter, T. E. (1990). Field drought tolerance of soybean plant introduction. *Crop Sci*. 30: 118-123.

[34] Tabatabaei, A. Shakeri, E. "Effect of cultivation pattern on performance and morphological characteristics of cotton cultivars", Agricultural researches, 2011, 3(3): pp. 307-318. [in Persian]

[35] Tian,X.R. and Lei, Y.B. ( 2007). Physiological responses of wheat seedlings to drough and UV.B radiation. Effect of exogenous sodium nitroprusside application. Russ J Plant Physiol.

[36] Toselli, M. E. and Casenave, E. C. (2003). Water content and the effectiveness of hydro and osmotic priming of cotton seeds. Seed Sci. and Techno. 31(3): 727-735.

[37] Zaifnejd, M. Clark, R. B. and Sullivan, C.Y. (1997) Alluminum and water stress effects on growth and proline of sorghum. J. *Plant Physiol*., 150(3): 338-344.