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Evaluation of the Effects of Moisture Stress on Qualitative and Quantitative Characteristics of Cotton Cultivars

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Abstract: **To evaluate the effects of moisture stress on yield and qualitative and quantitative characteristics of four cotton cultivars, an experiment was conducted using split plot arrangement in a randomized complete block design with four replications in Hashemabad Gorgan region. Main plots included three levels of irrigation (65 (I1), 100 (I2) and 135 (I3) mms cumulative evaporation from class A pan) and four cultivars consisting of Siokra (V1), Golestan (V2), Armaghan (V3) and Sahel (V4) assigned as sub plots. Studied traits were boll number, boll weight, and plant height, and leaf area, number of monopodial and sympodial branches, earliness, lint percentage and yield of plant. Two-year results showed that the effect of year was significant on boll weight, earliness, lint percentage and yield. The effect of irrigation was significant on total traits except for the number of sympodial branches. The effect of cultivar was significant on total traits. The interactional effect of irrigation and cultivar was significant on number of monopodial branches, boll number, boll weight and yield. Results showed that maximum number of monopodial branches, boll number and yield were obtained from cultivar of Siokra at the first level of irrigation (I1V1); and the maximum boll weight was obtained from cultivar Armaghan in no-stress condition (I1V2).**

Keywords: **Earliness, Cultivar of Siokra, Cotton Yield, Deficit Irrigation, Cotton.**

1. Introduction

Shortage of water resources and low rate of rainfall in our country make the future of agricultural productions unclarified. Uncontrolled exploitation of groundwater during the recent years also highlights the effects of drought (FathiSa' adabadi & Navvabi, 2008).

Studies have shown that water stress accompanied by change of rainfall patterns are considered as the main factors of reduced yield; and as the most important abiotic stress they have an important role on reduction of agricultural productions. Based on the conducted researches, among the factors causing stress such as diseases, pests, weeds, flooding, salinity and cold weather, water scarcity is solely the cause of 45% of reduction of yield (Sabaghpour, 2006). Thus studying and planning to formulate and provide an optimal pattern of water use in agriculture is inevitable.

Deficit irrigation is a strategy used for sustainable production of agricultural products during water scarcity; with this strategy the limit of water consumption reduction and yield per unit area are determined. Although by the use of deficit irrigation the plant somehow confronts water stress, by setting the stage for irrigation and optimization it is possible to have the maximum use from the water volume unit (Kimak et al., 2002). By the use of this method all farmers could have high efficient irrigation even in their farms. In the survey about improving water consumption for cotton irrigation results showed that in terms of water restriction, by reducing 51% of water consumption the profit from water volume unit will be equal to profit from full irrigation. In terms of water restrictions, by reducing 16% of water consumption the profit per unit area will be equal to profit from full irrigation (Fardad & ZeyghamiGol, 2006). Researches showed that deficit irrigation for different products results in increased water use efficiency without severe reduction of yield (Geerts and Raes, 2009). Basically plants chosen for deficit irrigation must be resistant to water stress and also its effects on the growth and yield during different stages of growth must be carefully examined (Göksoy et al., 2004).

Cotton (with scientific name of *Gossypium hirsutum* L) as a drought tolerant plant, is one of the industrial and strategic products of Golestan province that is resistant to water scarcity provided that it has proper management of irrigation (FathiSa' adabadi & Navvabi, 2008). Research results of Pereira et al (2009) showed that regulated deficit irrigation resulted from saving water and increasing the water use efficiency is suitable for cotton. While although severe deficit irrigation results in saving considerable amount of water, it also results in reduction of yield performance which may not be economically cost effective. Surveys have shown that although cotton is known as a compatible plant, different amount of irrigation has significant effects on yield performance of cotton (Onder et al., 2009). But indeed severe drought has hindered the growth of cotton plants and has resulted in creation of small cotton bolls and loss of flowers and buds; so that the effect of irrigation is completely obvious on traits such plant height, sympodial branches, boll weight and yield performance (Mc Williams, 2002). Results of one research showed that water tension during the flowering and boll creation period has high effect on physiological traits and chemical parameters of cotton such as leaf area development, photosynthesis, metabolism of carbon and nitrogen and also metabolism of antioxidants which ultimately could result in reduction of cotton yield (Ennahl & Earl, 2005). In order to offer better solutions for increasing the water use efficiency results showed that application of deficit irrigation method resulted in reduction of boll number and boll weight and ultimately reduction of cotton yield. Pix application causes reverse changes on the boll number and boll weight and results in a significant change on the cotton yield; but by accelerating the earliness of the product, the cotton becomes tolerant against deficit irrigation and it guarantees the longer survival of the plant in times of water scarcity (Hekmat et al., 2005). In researches by Necdet et al (2006) for surveying the deficit irrigation on cotton yield performance with five irrigation levels of 0, 30, 50, 70 and 100 percent of irrigation need, the highest yield performance was achieved from 100%. Similar results were reported by Bronson et al (2006) and Li et al (2002).

Based on the importance of irrigation during the summer time, water scarcity at this time and the agricultural products' need to water, deficit irrigation application becomes highly important. The current research aims to introduce the best cotton cultivar during deficit irrigation, while evaluating the reaction of four types of cotton to water deficit stress.

2. Materials & Methods

In order to evaluate the reaction of cotton cultivars to deficit irrigation, an experiment was conducted during two agricultural years of 2013 and 2014 in Hashemabad, Gorgan region. This region is situated at 11 kilometers northwest of Gorgan, with latitude 36 degrees and 55 minutes north, longitude 54 degrees and 20 minutes east and 14 meters above sea level.

The climate of the region is semi-moist and the average rainfall is 450-550 mms; the relative humidity is 50-60%, the average maximum and minimum temperature is 27.7 and 7.8˚C, respectively. Table 1 shows the weather data of Agricultural Research Station of Hashemabad during the 2-year growth season. The experiment was conducted using split plot arrangement in a randomized complete block design with four replications. Main plots included three levels of irrigation (65 (I_1), 100 (I_2) and 135 (I_3) mms cumulative evaporation from class A pan) and four cultivars consisting of Siokra (V_1), Golestan (V_2), Armaghan (V_3) and Sahel (V_4) assigned as sub plots. Studied traits were boll number, boll weight, and plant height, and leaf area, number of monopodial and sympodial branches, earliness, lint percentage and yield of plant. The soil of the farm had a loam-clam-silt texture with bulk density of 1.42 g/cm^3, and the moisture content at field capacity and permanent wilting point were 28% and 14%, respectively, and salinity of 0.5 ds/m and acidity of 7.9.

Table 1.Weather Data of Hashemabad Agricultural Research Station During the Growth Season.

Month	Average temperature(˚C)		Rainfall (mm)		Evaporation (mm)		RH (%)	
	2013	2014	2013	2014	2013	2014	2013	2014
Apr	16.9	17.6	59.9	45	120.2	122.1	69	67
May	23.4	25.7	30	24.2	197.1	199.1	62	61
Jun	27.8	28.2	3	1.1	205.4	207.3	63	60
Jul	29.4	29.5	11.7	10.1	206.2	208.2	65	63
Aug	28.2	30.8	18.9	13.2	161.1	163.1	68	67
Sept	27.4	27.4	66.6	48.4	108	109	68	67
Oct	20.2	20.2	24.7	12.1	63.2	65.4	71	70

The land was plowed in the fall of last year and in early spring two perpendicular disks were used for leveling, grinding lumps and mixing the fertilizer with the soil. Then the experimental units were made. Each plot had 5-row cultivation with length of 11 meters and cultivation row spacing of 80 cm and 20 cm. In order to prevent water leakage to the neighboring plots, the wall soil and furrow soil were pounded and compressed before irrigation and also the required space was considered. Based on the results of soil testing, except for nitrogen, the dosage of other fertilizers was added to the soil based on the soil testing and fertilizer recommendation before planting. A split application of nitrogen fertilizer was added to the soil at two stages of planting and flowering with top dressing method. 5 grams of Carboxin Thiram fungicide was used or sterilizing each kilogram of seeds. Planting during these two years was conducted on 30/Apr/2013 and 30/Apr/2014 with manual deficit irrigation. Cotton planting density at this experiment was 62500 plants per hectare. For reaching this density the planting was conducted by the use of Kopeh-kari method and 5 seeds were planted at each pile (Kopeh) and after growing, thinning method was used at two stages (4 and 6 leaf) in order to reach the desired density. Manual weeding was used for eliminating the weeds during the growth season and proper pesticides were used for eliminating pests. All plants were equally irrigated at the beginning of growth season and at the time of planting for reaching uniform germination and after the initial establishment stage and at 6-leaf stage all plants were irrigated.

Irrigation time was determined by the use of amount of daily evaporation from the Class A evaporation pan. For determining the volume of water consumption at each time of irrigation, soil sampling from the rooting depth of the plot was conducted before irrigating. The sample was kept in the oven under 80˚C for 24 hours. Then the moisture content of the soil was calculated and the irrigation water volume was determined through equation number 1 and 2 for each time of irrigation. Also the amount of water consumption was controlled by the use of a water meter at the beginning of the main water circle.

The experimental filed irrigation was conducted by the use of Hydroflume tubes and valves embedded at the beginning of lines of planting.

1) $H = \rho b (\theta_{F.C} - \theta_m) D$

2) $V = H \times A$

In number 1 and 2 equations H indicates the water height in the plot; pb indicates the bulk density, $\theta_{F.C}$ indicates the moisture at field capacity; θ_m indicates the mass moisture of the plot during irrigation; D indicates the depth of the root; V indicates the irrigation water volume and A indicates the area of plot. At the time of boll opening and before harvesting after eliminating 50 centimeters of beginning and end of each plot, 10 plants were randomly chosen and the traits of number of cotton bolls, boll weight, boll height, and plant height, and leaf area, number of monopodial and sympodial branches, earliness, lint percentage and yield of plantwere measured. Percentage of cotton yield at the first round of picking cottons was the earliness criterion. The final harvesting was conducted at two rounds of picking cottons during September and October and the product of each round of picking was harvested separately; and the weighing and total amount of picking rounds were considered as the cotton yield. Harvesting was conducted manually, from the middle rows of each plot and after eliminating the marginal effect. The logarithmic relationship of height and area of leaf was used or calculating the leaf area (FathiSa' adabadi & Navvabi, 2008).

$\text{Ln}(y) = 0.9091 + 1.5983\,\text{Ln}(x)$

Y: Leaf area (cm^2)

X: Plant height (cm)

Square analysis of data was conducted by the use of SAS 9.1 software. The average treatment was compared by the use of Duncan's multiple-range test at level 5%.

3. RESULTS &DISCUSSION

Results of combined variance analysis showed that the effect of irrigation treatments and the surveyed cultivars on plant height at probability level of 1% was significant (table 2). Edalatifard et al (2006) reported similar results; whereas the interactions between the treatments were insignificant. In other words, the process of changes of this trait under the influence of irrigation treatments in different cultivars was the same (table 2). Comparison between different levels of irrigation showed that the highest plant height was achieved for full irrigation treatment (I_1). Comparing the mean between the surveyed cultivars, the highest plant height was achieved for Armaghan and Sahel and then Siokra and Golestan (table 3). Studies conducted by Burke & Omahony (2001) showed that water scarcity results in slow growth, reduction of number of nodes and ultimately reduction of plant height. On the other hand, it seems that the difference between the plant heights among different cultivars could be related to their ability to use the environmental conditions (Tabatabaei & Shakeri, 2011). Results of a research showed that in comparison to other cultivars, due to its special form of leaf, cultivar Siokra allows more light-penetration into the plant community which reduces the competition for receiving light and its outcome is lack of increase of plant height (Panjeh koub et al., 2007).

Results achieved from this experiment indicated that the effect of irrigation, the surveyed cultivars and the interaction between irrigation and cultivars were statistically significant on the stem diameter at probability level of 1%. Changes of stem diameter and different cotton cultivars in different irrigation treatments showed that stem diameter increases during drought stress conditions (fig. 1; the reason to this change is development of vascular system for increasing the ability of plant to deliver water through the wooden vascular. It seems that this reaction of the plant is a kind of compatibility during deficit irrigation conditions (FathiSa' adabadi & Navvabi, 2008).

Results of combined variance analysis showed that the effect of irrigation treatments and the surveyed cultivars on leaf area at probability level of 1% was significant; whereas the effects of interactions between treatments were insignificant (table 2). Results of comparison of average deficit irrigation treatments showed that the lowest amount of leaf area was achieved for the third irrigation treatment (I_3). In other words, by increasing the intensity of stress, the leaf area was reduced in order to reduce evaporation. Also among the surveyed cultivars, due to the special form of leaves and deep cuts in the lamina, cultivar of Siokra had the lowest amount of leaf area (table 3). It seems that by starting the water stress, inhibition of cell growth results in reduced development of leaves and less leaf area results in less water uptake from the soil and less transpiration. Water scarcity may limit the development of canopy of the plant through affecting the number and size of leaves and also falling leaves. It has been reported that limited leaf area is the first defense line against drought (FathiSa' adabadi & Navvabi, 2008).

Based on the results of combined variance analysis the effect of irrigation, surveyed cultivars and the interaction between irrigation and cultivar were statistically significant on the number of monopodial branches at probability level 1% (table 2). In interaction between irrigation and cultivars the results showed that the highest number of monopodial branches was achieved from cultivar of Siokra with full irrigation (fig. 2). Similar results were reported by FathiSa' adabadi & Navvabi (2008).

Results of combined variance analysis indicated that cultivar treatment at probability level 1% was solely significant on the number of sympodial branches. Irrigation treatment and interactions between treatments was insignificant for this trait (table 2). Results of comparison of mean showed that cultivar of Siokra had the highest number of sympodial branches compared to other cultivars (table 3). Ghajari & Akramghaderi (2006) reported similar results.

Results of combined variance analysis indicated the significant effect of irrigation treatment, cultivar and interactions between irrigation and cultivar on the number of produced cotton bolls (table 2). Mean comparison between different levels of irrigation, the highest number of cotton bolls was 15.50 for treatment I_1 and the lowest number was 7.92 for I_3. Mean comparison between the surveyed cultivars for each year, the cultivars of Siokra and Sahel produced the highest and the lowest number of cotton boll for each plant (table 4); and these results are consistent with findings of Ghajari & Akramghaderi (2006). Mean comparison of interactions between irrigation and cultivar showed that the highest number of cotton boll was for cultivar of Siokra in no-stress condition (I_1V_1) (table 4). Generally, severe deficit irrigation results in considerable reduction in number of cotton bolls. Surveying the physiological and morphological reactions of cotton to water stress showed that severe water scarcity had resulted in reduced leaf development and flowering and plant's disability to keep the cotton bolls (White and Raine, 2004). On the other hand, it seems that in comparison between other cultivars, the cultivar of Siokra produced the highest amount of cotton bolls by the use of maximum environmental conditions.

Results of combined variance analysis indicated that the effect of year, irrigation treatment, and interactions between irrigation and cultivar were significant on the weight of boll (table 2). Results showed that there was a significant difference between years and the highest weight of boll was related to year 1 and this was related to the climate. In mean comparison between different levels of irrigation, I_1 treatment produced the biggest cotton bolls and I_3 treatment produced the smallest cotton bolls (table 4). Thus the water stress results in smaller bolls. Results of mean comparison showed that the effect of cultivar on weight of boll was completely significant; and in terms of weigh of boll the cultivar of Golestan had superiority over other treatments during both agricultural years (table 4). In interactions between irrigation and cultivar, the cultivar of Armaghan at irrigation level 1 (I_1V_2) produced the highest weigh of boll (table 4). Researches have shown that mild stress during growth season results in better absorption of photosynthetic materials through the reservoirs of sympodial organs compared to the reservoirs of monopodial organs; and this results in better survival of bolls and increase of number and weight of bolls and ultimately increased yield performance (White and Raine, 2004); on the other hand. Superiority of cultivar of Golestan in producing bigger bolls could be due to the higher fiber index and seed index compared to other cultivars (Javadi et al., 2005).

Data analysis results showed that the effect of year, irrigation treatments and cultivar at probability level 1% was significant on earliness. The interactions between irrigation and cultivar related to the earliness trait were statistically insignificant (table 2). In year 1 there was no significant difference between different irrigation treatments in terms of percentage of earliness but in year 2 the highest and lowest percentage of earliness belonged to I_3 treatment (severe stress) and I_1 (full irrigation), respectively. Also results of mean comparison showed that among the cultivars of percentage of earliness, the cultivar of Sahel was less than other cultivars and cultivars of Siokra, Golestan and Armaghan were categorized together in terms of earliness and cultivar of Sahel was separated (table 4). Surveys indicated the reduced growth period and earliness of production due to water stress; perhaps different factors such as environmental conditions and cultivars were effective on change of results of deficit irrigation and earliness of surveyed cultivars of cotton (Donyavian & Ranjbar, 2007). Early cultivars could grow more quickly and escape the drought (Ramezani Moghadam & Taherian, 2004). Due to shorter period of growth these cultivars need less water and irrigation which is an important matter during the droughts in regions having water problems and this is considered as an advantage to them (Sa'adabadi & Navvabi, 2008).

Results of combined variance analysis showed that the effect of year, irrigation treatments and cultivar was statistically significant on lint percentage at probability level 1%. The interactions between irrigation and cultivar were insignificant (table 2). In mean comparison of different levels of irrigation, I_3 treatment (severe stress) resulted in reduction of lint percentage. Results of mean comparison between the surveyed cultivars showed that highest lint percentage belonged to cultivar of Siokra (table 5). Any kind of environmental stress results in reduction of photosynthesis reserves of the plant reduction of fiber length (Philip et al., 2000). Results of combined variance analysis indicated the significant effect of year, irrigation treatments, cultivar, and effect of interactions between irrigation and cultivar on yield performance at probability level 1% 9table 2). Results showed that there was a significant difference between years and cotton yield during the year 1 was higher. Full irrigation treatment (I_1) with yield performance of 3270.50 had the best performance compared to I_2 and I_3 treatments. Also there was a statistically significant difference between these three treatments; on the other hand, the process of reduced water application was consistent with the process of reduced production in I_2 and I_3 treatments (table 5). These results were similar to the results of Dagdelen et al., 2006) and Yazar et al (2002). In mean comparison between the surveyed cultivars, the cultivar of Siokra produced the highest cotton yield during the two years (table 3). Mean comparison of interactions between irrigation and cultivar showed that cultivar of Siokra in no moisture stress conditions produced the highest cotton yield (table 5). It seems that certain weather conditions such as rainfall changes, increased temperature, and evaporation during the flowering of cotton resulted in reduced yield performance in year 1. Sa'adabadi & Navvabi (2008) reported similar results. The highest and lowest coefficient of sensitivity to stress belonged to cultivars of Sahel and Siokra (Emami et al., 2008). It seems that cultivar of Sahel showed more sensitivity during monopodial growth than sympodial growth at different irrigation conditions and it had the highest height but the lowest yield.

Table 2.Results of Combined Variance Analysis of Traits of Cotton Cultivars under the Influence of Irrigation

Mean Square											
Variationsources	Df	Height of plant	Stem diameter	Leaf area	No. of empodial branches	No. of sympodial branches	No. of boll	weight of 20bolls	Earliness	Lint percentage	Yield
(Y) Year	1	236.66^{ns}	0.00^{ns}	503730.38^{ns}	0.00^{ns}	0.00^{ns}	0.00^{ns}	864.00^{**}	283.59^{**}	216.00^{**}	1900125.37^{**}
Year/ replications	6	2.45^{ns}	0.17^{ns}	253867.82^{ns}	0.02^{ns}	1.01^{ns}	0.18^{ns}	75.75^{*}	31.09^{ns}	6.39^{ns}	33473.74^{ns}
(I) Irrigation	2	3896.47^{**}	57.99^{**}	2497616.70^{**}	37.05^{**}	4.02^{ns}	549.53^{**}	8494.79^{**}	155.76^{**}	1363.17^{**}	33858451.79^{**}
Y×I	2	0.02^{ns}	0.00^{ns}	35350.03^{ns}	0.00^{ns}	0.00^{ns}	0.00^{ns}	0.00^{ns}	89.65^{*}	0.00^{ns}	76022.00^{ns}
Main error	12	62.24	0.25	34574.77	0.04	1.74	0.60	45.25	10.92	2.72	84878.92
(V) Cultivar	3	2802.20^{**}	142.34^{**}	10783178.15^{**}	5.24^{**}	174.12^{**}	77.37^{**}	6351.15^{**}	5326.93^{**}	111.67^{**}	7009369.74^{**}
I×V	6	177.72^{ns}	18.88^{**}	34638.35^{ns}	1.05^{**}	2.30^{ns}	15.63^{**}	1091.82^{**}	17.97^{ns}	5.00^{ns}	1182185.24^{**}
V×Y	3	0.07^{ns}	0.00^{ns}	250346.15^{ns}	0.00^{ns}	0.00^{ns}	0.00^{ns}	0.00^{ns}	171.70^{**}	0.00^{ns}	103119.57^{*}
I×V×Y	6	0.05^{ns}	0.00^{ns}	34638.35^{ns}	0.00^{ns}	0.00^{ns}	0.00^{ns}	0.00^{ns}	55.98^{*}	0.00^{ns}	90277.28^{*}
Minor error	54	183.98	1.04	164002.65	0.03	1.31	0.39	27.63	24.28	6.09	32702.8
Coefficientof % Variation		15.72	9.83	8.43	7.17	14.35	5.83	6.84	7.83	8.25	8.66

ns, *, **, are insignificant and significant at levels 5 and 1%, respectively.

Table 3.Mean Comparison of Simple Effect and Interactions BetweenIrrigation and Cultivar in Combined Decomposition During 2013 and 2014 on the Surveyed Traits.

	Plant height (cm)			(Leaf area (cm2			No. of sympodial branches in		
Treatment	2013	2014	Combined decomposition of two years	2013	2014	Combined decomposition of two years	2013	2014	Combined decomposition
Cumulative									
65mm (I_1)	98.96^{a}	95.87^{a}	97.41^{a}	2388.00^{a}	2199.69^{a}	2293.97^{a}	8.33^{a}	8.33^{a}	8.33^{a}
100mm (I_2)	87.66^{b}	84.53^{b}	86.09^{b}	1988.00^{b}	1810.56^{b}	1899.41^{b}	8.02^{a}	8.02^{a}	8.02^{a}
135mm (I_3)	76.94^{c}	73.75^{c}	75.35^{c}	1788.00^{c}	1719.88^{b}	1754.06^{c}	7.62^{a}	7.62^{a}	7.62^{a}
Cultivars (V)									
(V_1)Siokra	76.18^{b}	73.17^{b}	74.67^{b}	1299.70^{d}	1190.40^{c}	1245.00^{d}	11.23^{a}	11.23^{a}	11.23^{a}
(V_2)	81.69^{b}	78.57^{b}	80.13^{b}	1677.40^{c}	1627.30^{bc}	1652.40^{c}	9.15^{b}	9.15^{b}	9.15^{b}
(V_3)	93.60^{ab}	90.45^{ab}	92.03^{a}	2255.70^{b}	2276.30^{ab}	2266.00^{b}	6.19^{c}	6.19^{c}	6.19^{c}
(V_4)Sahel	99.95^{a}	96.67^{a}	98.31^{a}	2986.90^{a}	2546.20^{a}	2766.50^{a}	5.40^{c}	5.40^{c}	5.40^{d}
Evaporation									
$I_1 \times V_1$	86.75^{bcd}	83.75^{bcd}	85.25^{bcd}	1633.00^{h}	1531.50^{d}	1582.25^{de}	11.17^{a}	11.17^{a}	11.17^{a}
$I_1 \times V_2$	89.60^{bc}	86.60^{bc}	88.10^{bc}	2010.75^{f}	1959.50^{c}	1985.13^{cd}	9.26^{b}	9.26^{b}	9.26^{b}
$I_1 \times V_3$	101.39^{b}	98.36^{b}	99.88^{b}	2589.00^{d}	2608.00^{ab}	2598.50^{ab}	6.98^{c}	6.98^{c}	6.98^{c}
$I_1 \times V_4$	118.11^{a}	114.75^{a}	116.43^{a}	3320.25^{a}	2699.75^{a}	3010.00^{a}	5.90^{cd}	5.90^{cd}	5.90^{cd}
$I_2 \times V_1$	79.25^{cd}	76.25^{cd}	77.75^{cd}	1233.00^{k}	1114.00^{ef}	1173.50^{ef}	11.13^{a}	11.13^{a}	11.13^{a}
$I_2 \times V_2$	82.88^{cd}	79.85^{cd}	81.36^{cd}	1610.75^{i}	1562.25^{d}	1586.50^{de}	9.04^{b}	9.04^{b}	9.04^{b}
$I_2 \times V_3$	94.36^{bc}	91.25^{bc}	92.81^{bc}	2189.00^{e}	2209.50^{bc}	2199.25^{bc}	5.98^{cd}	5.98^{cd}	5.98^{cd}
$I_2 \times V_4$	94.13^{bc}	90.75^{bc}	92.44^{bc}	2920.25^{b}	2356.50^{abc}	2638.38^{a}	5.96^{cd}	5.96^{cd}	5.96^{cd}
$I_3 \times V_1$	62.53^{e}	59.50^{e}	61.01^{e}	1033.00^{l}	925.75^{f}	979.38^{f}	11.39^{a}	11.39^{a}	11.39^{a}
$I_3 \times V_2$	72.60^{de}	69.25^{de}	70.93^{de}	1410.75^{j}	1360.25^{de}	1385.50^{ef}	9.14^{b}	9.14^{b}	9.14^{b}
$I_3 \times V_3$	85.05^{bcd}	81.75^{cd}	83.40^{cd}	1989.00^{g}	2011.25^{c}	2000.13^{cd}	5.62^{cd}	5.62^{cd}	5.62^{d}
$I_3 \times V_4$	87.60^{bcd}	84.50^{bcd}	86.05^{bcd}	2720.25^{c}	2582.25^{ab}	2651.25^{a}	4.34^{d}	4.34^{d}	4.34^{e}

In each column related to the factor, the letters indicate the significant difference between mean of treatments.

Table 4. Mean comparison of simple effects and interactions between irrigation and cultivars in combined decomposition during 2013 and 2014 on the surveyed traits.

	No. of bolls in plant			weight of 20 bolls (gr)			(%) Earliness		
Treatment	2013	2014	Combined decomposition of 2 years	2013	2014	Combined decomposition of 2 years	2013	2014	Combined decomposition
Cumulative evaporation									
65mm (I_1)	15.50^{a}	15.50^{a}	15.50^{a}	98.44^{a}	92.44^{a}	95.44^{a}	60.81^{a}	60.81^{c}	60.81^{c}
($_2$I) mm100	8.80^{b}	8.80^{b}	8.80^{b}	73.11^{b}	67.11^{b}	70.11^{b}	61.00^{a}	64.63^{b}	62.81^{b}
135mm (I_3)	7.92^{c}	7.92^{c}	7.92^{c}	68.02^{c}	62.02^{c}	65.02^{c}	61.88^{a}	68.56^{a}	65.22^{a}
Cultivars (V)									
Siokra (V_1)	12.88^{a}	12.88^{a}	12.88^{a}	83.10^{b}	77.10^{b}	80.10^{b}	67.50^{a}	71.33^{a}	69.42^{a}
Golestan (V_2)	11.14^{b}	11.14^{b}	11.14^{b}	100.83^{a}	94.83^{a}	97.83^{a}	67.17^{a}	74.33^{a}	70.75^{a}
Armaghan (V_3)	10.40^{c}	10.40^{c}	10.40^{c}	72.76^{c}	66.76^{c}	69.76^{c}	67.50^{a}	74.50^{a}	71.00^{a}
Sahel (V_4)	8.55^{d}	8.55^{d}	8.55^{d}	62.74^{d}	56.74^{d}	59.74^{d}	42.75^{b}	38.50^{b}	40.63^{b}
Evaporation ×									

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Cultivar (I×V)									
$I_1 \times V_1$	16.95^{a}	16.95^{a}	16.95^{a}	104.67^{b}	98.67^{b}	101.67^{b}	66.00^{a}	69.00^{c}	67.50^{c}
$I_1 \times V_2$	15.32^{c}	15.32^{c}	15.32^{c}	113.97^{a}	107.97^{a}	110.97^{a}	66.00^{a}	70.25^{c}	68.13^{bc}
$I_1 \times V_3$	16.18^{ab}	16.18^{ab}	16.18^{b}	99.69^{bc}	93.69^{bc}	96.69^{bc}	66.25^{a}	69.00^{c}	67.63^{c}
$I_1 \times V_4$	13.55^{c}	13.55^{c}	13.55^{d}	75.44^{de}	69.44^{de}	72.44^{f}	45.00^{b}	35.00^{e}	40.00^{d}
$I_2 \times V_1$	9.89^{e}	9.89^{e}	9.89^{f}	62.92^{fg}	56.92^{fg}	59.92^{g}	65.50^{a}	72.75^{abc}	69.13^{bc}
$I_2 \times V_2$	8.92^{ef}	8.92^{ef}	8.92^{g}	95.15^{c}	89.15^{c}	92.15^{cd}	66.25^{a}	74.75^{abc}	70.50^{abc}
$I_2 \times V_3$	8.61^{fg}	8.61^{fg}	8.61^{g}	62.98^{fg}	56.98^{fg}	59.98^{g}	66.00^{a}	74.75^{abc}	70.38^{abc}
$I_2 \times V_4$	7.78^{g}	7.78^{g}	7.78^{h}	71.41^{ef}	65.41^{ef}	68.41^{f}	46.25^{b}	36.25^{e}	41.25^{d}
$I_3 \times V_1$	11.81^{d}	11.81^{d}	11.81^{e}	81.72^{d}	75.72^{d}	78.72^{e}	71.00^{a}	72.75^{bc}	71.63^{abc}
$I_3 \times V_2$	9.18^{ef}	9.18^{ef}	9.18^{g}	93.39^{c}	87.39^{c}	90.39^{d}	69.25^{a}	78.00^{ab}	73.63^{ab}
$I_3 \times V_3$	6.40^{h}	6.40^{h}	6.40^{i}	55.61^{g}	49.61^{g}	52.61^{h}	70.25^{a}	79.75^{a}	75.00^{a}
$I_3 \times V_4$	4.31^{i}	4.31^{i}	4.31^{j}	41.38^{h}	35.38^{h}	38.38^{i}	37.00^{c}	44.25^{d}	40.63^{d}

In each column related to the factor, the similar letters indicate the insignificant difference between mean of treatments.

Table 5.Mean Comparison of Simple Effects and Interactions BetweenIrrigation and Cultivar in Combined Decomposition During 2013 and 2014 on the Surveyed Traits.

	Lint percentage			Yield performance (kg/hectare)		
Treatment	2013	2014	Combined decomposition of 2 years	2013	2014	combined decomposition
Cumulative evaporation (I)						
65mm (I_1)	38.88^{a}	35.88^{a}	37.38^{a}	3354.94^{a}	3186.06^{a}	3270.50^{a}
100mm (I_2)	28.63^{b}	25.63^{b}	27.13^{b}	1769.31^{b}	1428.44^{b}	1598.88^{b}
135mm (I_3)	26.75^{c}	23.75^{c}	25.25^{c}	1563.38^{c}	1229.00^{c}	1396.19^{c}
Cultivars (V)						
(V_1) Siokra	34.08^{a}	31.08^{a}	32.58^{a}	2880.33^{a}	2536.33^{a}	2708.33^{a}
(V_2) Golestan	31.67^{b}	28.67^{b}	30.17^{b}	2463.42^{b}	2036.17^{b}	2263.29^{b}
(V_3) Armaghan	31.08^{bc}	28.08^{bc}	29.58^{b}	2102.67^{c}	1819.75^{c}	1961.21^{c}
(V_4) Sahel	28.83^{c}	25.83^{c}	27.33^{c}	1470.42^{d}	1372.08^{d}	1421.25^{d}
Evaporation ×Cultivation (I×V)						
$I_1 \times V_1$	41.50^{a}	38.50^{a}	40.00^{a}	3911.25^{a}	3567.25^{a}	3739.25^{a}
$I_1 \times V_2$	39.00^{a}	36.00^{a}	37.50^{a}	3678.50^{ab}	3174.75^{b}	3431.13^{b}
$I_1 \times V_3$	39.50^{a}	36.50^{a}	38.00^{a}	3518.75^{b}	3343.50^{ab}	3431.31^{b}
$I_1 \times V_4$	35.50^{b}	32.50^{b}	34.00^{b}	2302.25^{d}	2658.75^{c}	2480.50^{c}
$I_2 \times V_1$	31.50^{c}	28.50^{c}	30.00^{c}	2043.75^{de}	1699.75^{e}	1871.75^{d}
$I_2 \times V_2$	29.00^{cde}	26.00^{cde}	27.50^{cd}	1824.75^{e}	1480.75^{ef}	1652.75^{e}
$I_2 \times V_3$	28.25^{cdef}	25.25^{cdef}	26.75^{de}	1719.00^{ef}	1375.00^{ef}	1547.00^{e}
$I_2 \times V_4$	25.75^{def}	22.75^{def}	24.25^{ef}	1489.75^{f}	1158.25^{f}	1324.00^{f}
$I_3 \times V_1$	29.25^{c}	26.25^{cd}	27.75^{cd}	2686.00^{c}	2342.00^{d}	2514.00^{c}
$I_3 \times V_2$	27.00^{def}	24.00^{def}	25.50^{def}	1878.00^{e}	1534.00^{e}	1706.00^{de}
$I_3 \times V_3$	25.50^{ef}	22.50^{ef}	24.00^{f}	1070.25^{g}	740.75^{g}	905.50^{g}
$I_3 \times V_4$	25.25^{f}	22.25^{f}	23.75^{f}	619.25^{h}	299.25^{h}	459.25^{h}

In each column related to the factor, the similar letters indicate the insignificant difference between mean of treatments.

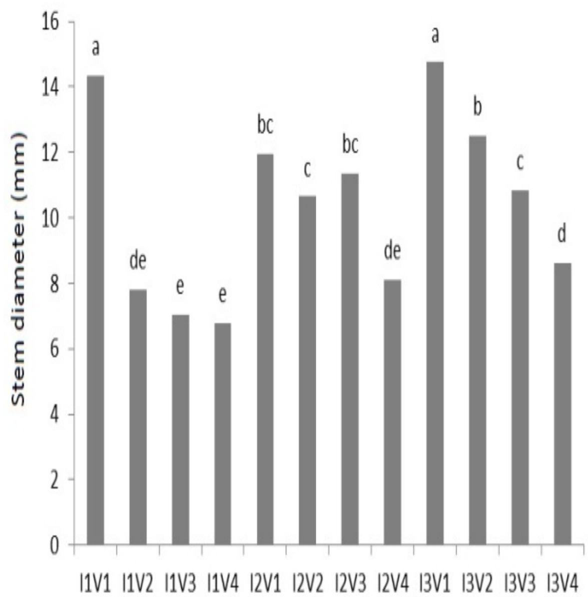

Fig.1. Stem Diameter Changes in Cultivars of Cotton During Different Irrigation Treatments.

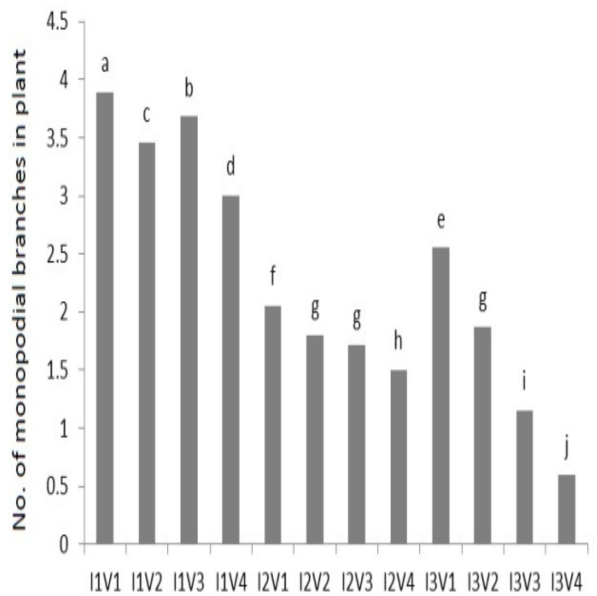

Fig.2. Changes of No. of Monopodial Branches in Cultivars of Cotton DuringDifferent Irrigation Treatments.

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