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Water Use Efficiency of Common Sorghum and Grain Corn Cultivars and Comparing the Effect of Water Deficit on These Cultivars

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Abstract

Drought stress is the most important abiotic factor which limits the growth and production of plants in arid and semi-arid regions. In order to investigate the effects of irrigation regimes (100, 80 and 60% of the plant's water requirement based on the Penman-Monteith method) on grain yield of sorghum (Payam and Kimia) and corn (704 and Maxima) cultivars under the hot and dry climate of Isfahan, a split plots experiment was carried out in the years 2018-2019 in randomized complete blocks design with three replications. Results showed that the highest index of chlorophyll and grain fat was obtained from cultivar 704 and in 100% of irrigation. Cultivar 704 produced the highest grain lignin under 60% and 80% irrigation regimes. Kimia cultivar produced more lignin compared to Payam cultivar. Payam cultivar produced the most yield and the highest plants under irrigation regimes of 100 and 80. Compared to Payam cultivar, Kimia showed more 1000 grains weight under different irrigation regimes. The harvest indices of Kimia and Payam cultivars showed significant decreases by increasing the drought. Different cultivars have different mechanisms to tolerate drought stress. As a drought tolerant plant, Sorghum was less damaged by stress than corn. Biochemical traits of plants can be used as stress resistance indicators in breeding programs and the selection of resistant cultivars.

***Keywords**:* Grain fat, Harvest index, Drought stress, Grain yield, Grain lignin

INTRODUCTION

Water is one of the most important limiting factors of plants' growth and production, especially in arid and semi-arid regions. Agricultural plants are continuously exposed to water shortage stress and react to stress in various ways. Understanding these reactions will significantly help to describe the growth and production rate of plants under environmental stress (Sarshad *et al*., 2019). Investigations on irrigation management (irrigation intervals and depth) to determine the response of yield to water have led to water and yield production functions, which can be used to increase water consumption efficiency (Badr *et al*., 2020). The resistance of plants to drought stress is a very complex mechanism due to the complicated interactions between stress factors and various physiological, biochemical and molecular phenomena which affect the growth and development of plants. Therefore, it seems necessary to know the effects of drought stress on plants (Hui-Ping *et al*., 2012). One of the proposed solutions to improve the management of irrigation efficiency is to achieve good yield concerning the maximum efficiency of irrigation water. In this regard, knowing the relationship between soil water deficiency and crop growth, investigating the physiological reactions related to stress, cultivating tolerant plants and other things that provide the possibility of developing more plants in arid and semi-arid regions will be valuable and desirable. For this reason, identifying new methods of irrigation and low irrigation are measures that can reduce the consequences of water shortage and drought stress (Nxele *et al*., 2017). Low irrigation is an intelligent solution to optimize water use, in which the plant is consciously allowed to reduce its yield by receiving less water than the required amount and tolerate water stress during the growing season (Zegaoui *et al*., 2017).

The response of agricultural plants to drought stress has been the subject of many articles from biochemical, physiological and agricultural aspects (Tarawneh *et al*., 2019). One of the critical issues of cultivar evaluation for drought resistance is the quantitative measurement of drought resistance criteria (Akram *et al*., 2013). These criteria, which are evaluated based on crop yield of both stressed and non-stressed environments, can be used by breeders for selecting drought-resistant genotypes (Amoah and Antwi-Berko, 2020). Grain yield is one of the most important characteristics for selecting drought-tolerant genotypes and in plant breeding, the target is high yield genotypes under both drought conditions and regular irrigation (Sah *et al*., 2020; Bell *et al*., 2020).

Sorghum (*Sorghum bicolor* (L.) Moench) is known as an indicator of drought-resistant crops due to its unique morphological and physiological characteristics. Compared to other crops, sorghum is more resistant to hot and difficult irrigation conditions and needs less water. The cultivated area of sorghum in the world is about 42.4 million hectares and 90% of this cultivated area is belongs to grain cultivars (Khazaei *et al*., 2016). Sorghum, having characteristics such as small apertures, self-folding of leaves, control of apertures and, is highly adaptable to a wide range of ecological conditions compared to the other crops. This plant can produce a lot under dry conditions if there is enough moisture in the stage of clustering and flowering. It can to reduce its growth rate during a dry period and can resume its growth when the moisture conditions improve (Akbudak *et al*., 2018).

Drought stress is the most important growth and yield limiting factor of cereals, including corn (*Zea mays* L.). Corn is a C4 plant, which is the third most important crop in the world after wheat and rice. The water supply required for the specific stages of vegetative and reproductive growth of corn is of particular importance (Sah *et al*., 2020). The adverse effects of water stress on the growth and yield of corn depend on the time of occurrence of the stress, the intensity of the stress, the developmental stage and the genotype of the plant. Considering the water requirement of corn, the lack of water for its proper production is one of the essential problems of the country. Since there is little rainfall and limited water resources in our country, it is essential to use the available water optimally. The minimum water should be used as much as possible so that more area can be cultivated (Zarrabi *et al*., 2016). Many researches indicate a high and positive correlation between the genetic improvement of grain yield and the number of grains per square meter and harvest index (Wu *et al*., 2017). Greaves and Wang (2017) reported significant effect of drought stress on corn grain yield with highest grain yield of 1008 grams per square meter. They mentioned drought stress led to a 33% decrease in grain yield. Alderfasi *et al*. (2016) investigated the Gizani cultivar under three irrigation cycles of 6, 9 and 12 days in Saudi Arabia they reported that the yield and yield components were significantly affected by increasing the irrigation cycle.

Considering that the selection of drought-resistant cultivars and studying the behavior of different genotypes against drought stress are of particular importance to understanding the mechanisms of drought resistance (Reddy, 2019), studying stress factors and their effects on crops and developing methods to deal with environmental stress seems to be very vital, especially in our country. Considering the possibility of drought during the growing season of corn and sorghum plants, it is necessary to investigate the effects of stress on changes in yield and yield components as well as the growth and biochemical parameters of these plants to evaluate the plant's response to drought stress. Because different ecotypes which grow in different climatic conditions can show different reactions to the lack of soil moisture, this study was conducted to identify cultivars with high production potential under limited water conditions. For this purpose, the effects of different irrigation regimes on grain yield and biochemical characteristics of grain corn cultivars (Maxima and 704) and grain sorghum cultivars (Kimiya and Payam) were investigated in this research and the response of these plants cultivars to water deficiency was compared to be introduced in agricultural recommendations.

MATERIALS AND METHODS

In order to determine the water efficiency of common sorghum and corn grain cultivars and compar the effects of different water deficit levels, two split plots experiments were carried out in randomized complete blocks design with three replications in the northwestern region of Isfahan (2018-2019). In these quantitative studies, grain sorghum cultivars (Payam and Kimia) and grain corn cultivars (704 and Maxima) were compared with the amount of water consumed. In both experiments, the main plots were different irrigation regimes (regular irrigation, mild drought stress and severe drought stress) including irrigation regimes of 100%, 80% and 60%, respectively. Sub-plots were common cultivars of grain sorghum and grain corn.

First, the land was deeply plowed and ammonium phosphate and potassium sulfate fertilizers were placed under the soil using a disc based on the soil test. Other seedbed preparation operations were carried out in the spring when the weather was favorable. Plants were planted when the soil temperature reached 12⁰ C. Each sub-plot consisted of four planting lines of six meters in length, where two middle lines were considered as harvest rows and two side lines were considered as the borders of the statistical population. Sorghum was planted with a density of 170,000 plants per hectare in the middle of 60 cm inter rows distance and 10 cm distance between plants on the rows. These amounts were 75,000 thousand plants, 75 cm and 17 cm for corn, respectively.

Different irrigation regimes were applied after the establishment of seedlings (four leaves stage). At the height of about 40 cm of the plants, nitrogen fertilizer (Urea) was applied in strips next to the rows. The desired traits were measured during the growing season. Drip-strip irrigation was used and the irrigation cycle was determined based on humidity changes and plant water requirements. By obtaining the required meteorological data from Isfahan Meteorology station, plant's water requirement was calculated based on the reference plant's daily evapotranspiration (ETo) and plant coefficient (Kc) using the combined model of Penman-Monteith FAO 56.

Finally, the depth of irrigation water was calculated by considering the application efficiency of three treatments of 60, 80 and 100% in the strip drip system. The volume of water used in the irrigation treatments was measured by calibrated volumetric meters. To measure the grain yield, two square meters of each plot were selected after physiological ripening, observing the margin (Rafii Menesh et al., 2018). The harvest index was calculated using equation (1) (Rafii Menesh *et al*., 2018).

(1) Harvest index= (dry weight of grain yield/dry weight of biological yield) × 100

After physiological ripening, the height of the plant from the soil surface to the end of the panicle was measured using a ruler. To determine the weight of 1000 grains, five hundred random samples of grains were weighed and the weight of 1000 grains was calculated based on the moisture content of 14% (Eivazi *et al*., 2011).

Fat percentage was measured using the solvent extraction method and Soxhlet apparatus (Ghanbari *et al*., 2018). The lignin content was evaluated according to the method of Van Soest and Wein (1991) and the optical absorption of the samples was read at a wavelength of 280 nm by a spectrophotometer. The chlorophyll index was measured by the Spad device (model CL-01).

Obtained data were analyzed using SAS software and mean comparison was performed based on Duncan's multi-range test at a probability level of 5%.

RESULTS AND DISCUSSION

Grain yield

Variance analysis results showed that the simple and interaction effects of irrigation and cultivar on the yield of corn were not significant at the 5% probability level (Table 1). Also, mean comparison results of irrigation, cultivar and the interaction of these treatments showed no significant differences (Tables 2 and 3). The grain yield of sorghum was affected by the cultivar significantly ($p<0.05$). However, the interaction of cultivar and irrigation did not have a significant effect on this trait (Table 4). Mean comparison results also indicated the effect of the cultivar on the grain yield, and among the examined cultivars, Payam had the highest yield (6650.89 kg/ha). Also, the highest grain yield was obtained from 100% and 80% irrigation regimes (Table 5). The results showed that Payam cultivar showed the highest grain yield under 100 and 80% irrigation regimes compared to the 60% irrigation regime and Kimia cultivar (Table 6). The grain yield and biochemical characteristics of the studied cultivars of both plants showed different results under different irrigation regimes.

Examining the differences between different levels of drought stress shows the ability of the plant to adapt and cope with drought conditions. By increasing the drought, sorghum's grain yield showed a significant decrease. The reason could be disrupting the plant's physiological activities under stress conditions (Ali *et al*., 2009). The researchers reported that drought stress reduces growth and net photosynthesis, and as a result, reduces biomass and grain yield.

Table 1. Variance analysis of cultivar and irrigation effects on some morphological and biochemical traits of corn

Sources of changes	d.f	average of squares						
		grain yield	harvest index	grain fat	grain lignin	Chlorophyll index	Plant height	1000 grains weight
Block	2	0.36 ^{ns}	0.06 ^{ns}	0.09 ^{ns}	0.001 ^{ns}	14.03*	292.01 ^{ns}	1506.68 ^{ns}
Irrigation	2	0.24 ^{ns}	0.08 ^{ns}	0.98 **	0.003 ^{ns}	7.59 ^{ns}	1747.50**	209.76 ^{ns}
Error A	4	0.17	0.04	0.02	0.0008	6.99	49.43	457.37
Cultivar	1	0.10 ^{ns}	0.04 ^{ns}	0.08 ^{ns}	0.03 ^{ns}	14.69*	0.11 ^{ns}	788.71 ^{ns}
Irrigation × Cultivar	2	0.06 ^{ns}	0.01 ^{ns}	0.05 ^{ns}	0.008 ^{ns}	1.07 ^{ns}	1188.30**	145.86 ^{ns}
Error b	6	0.36	0.07	0.35	0.006	1.75	77.94	1200.62

^{ns} non-significant, * and ** significant at 5 and 1 percent probability level, respectively.

Drought stress in the grain filling stage affects the amount of biomass production and grain yield by reducing the growth of leaves, the concentration of chlorophyll, stomatal conductance, the concentration of soluble proteins and finally the rate of photosynthesis and accelerating the aging of leaves (Meher ShivaKrishna *et al*., 2018). Of course, the amount of damage depends on the intensity and duration of the stress, as well as the resistance of the plant and the growth stage in which the plant is located. The decrease in grain yield may be due to the effects of drought stress on the supply of the required nutrients for filling grains, the decrease in sink capacity to absorb photosynthetic materials, and the shortening of the growth period. The initial events related to grain growth, including cell division and formation of sink size, may be less affected by drought stress. The findings of other researchers also confirm this (Saeidi *et al*., 2010).

Harvest Index

The effects of cultivar, irrigation and the interaction of these treatments were not significant ($p>0.05$) on harvest index of corn plants (Table 1). Mean comparisons also showed no difference between treatments and their interaction (Tables 2 and 3). Cultivar affected the harvest index of sorghum (Table 4) significantly ($p<0.01$). Payam cultivar had a higher harvest index (25.72%) than Kimia cultivar (10.61%) (Table 5). According to the results of Table 6, the harvest index showed a significant decrease in sorghum cultivars, by increasing the drought stress. However, no statistically significant difference was observed for the harvest index of Kimia between different irrigation regimes.

Researchers have reported that because the harvest index indicates the genetic potential of economic performance, its high values for a genotype under regular irrigation can also bring high performance under drought stress. In addition to reducing the production of dry matter, drought stress caused a disruption in the distribution of carbohydrates to the grain and reduced the harvest index. Since grain yield is one of the harvest index components, changes in the harvest index depend highly on yield changes (Sarshad *et al*., 2019).

Grain Fat

The effects of cultivar on the fat content of corn grains were not significant at a 5% probability level (Table 1). The amount of grain fat was decreased significantly under the irrigation regime of 60% (2.5%) and the highest amounts of grain fat were obtained from the irrigation regimes of 100% and 80% with the amount of 3.20% and 3.19%, respectively (Table 2). Cultivar, irrigation and their interaction didn't affect fat content of sorghum at 5% probability level (Table 4). Means comparison results also did not show any significant effect ($p>0.05$) of treatments (Tables 5 and 6).

According to the results, the fat content of corn grains was decreased under severe drought stress (60%). The decrease can be due to disturbance in the metabolic processes of grains and assimilates transferring. Also, the shortening of the grain filling period, caused by an increase in temperature and drought stress and changes in the metabolism of materials, can lead to decreased fat. Drought stress has reduced the percentage of fat during ripening which is due to the acceleration of ripening. These findings are consistent with the results of Sarshad *et al*. (2019) on grain sorghum.

Table 2. Mean comparison results of some corn's morphological and biochemical traits (simple effects of cultivar and irrigation)

	Treatment	grain yield (kg/ha)	harvest index (%)	grain fat (%)	grain lignin (%)	Chlorophyll index (spad)	Plant height (cm)	1000 grains weight (gr)
Irrigation regimes (%)	100	2669.07[a]	15.81[a]	3.20[a]	2.67[b]	8.64[a]	214.13[a]	295.73[a]
	80	1631.98[a]	9.56[a]	3.19[a]	2.71[b]	7.98[a]	188.10[b]	287.42[a]
	60	1002.53[a]	6.52[a]	2.50[b]	3.03[a]	6.45[a]	182.00[b]	284.28[a]
Cultivar	704	2166.58[a]	12.89[a]	3.03[a]	3.20[a]	8.59[a]	194.82[a]	295.76[a]
	Maxima	1369.14[a]	8.37[a]	2.90[a]	2.41[a]	6.78[b]	194.67[a]	282.52[a]

The difference of numbers with at least one common letter in each column is not significant at the 5% level according to Duncan's test.

Grain Lignin

The effects of cultivar, irrigation and their interaction effect on the lignin content of corn grains were not significant at 5% probability level (Table 1). According to the results of table (3), cultivar 704 showed the highest amount of grain lignin under 60 and 80% irrigation regimes (3.50 and 3.37 %, respectively), In contrast, Maxima under 100% irrigation regime had the lowest amount of this trait (1.92%). Cultivar significantly affected ($p<0.05$) the lignin content of sorghum grains (Table 4). Kimia showed higher lignin content (2.44%) than Payam cultivar (2.00%) (Table 5). The results showed that the amount of corn lignin increased significantly under drought stress. Increased lignin of cell wall structure can be a reason for higher biomass of plants, especially under drought stress (Rezai Chiane and Pirzad, 2013).

Chlorophyll Index

Variance analysis results showed that the effect of cultivar on the chlorophyll index of corn was significant at the 5% probability level (Table 1) while the effect of irrigation on this trait was not significant ($p>0.05$). The highest chlorophyll index (8.59) was related to 704 cultivar and Maxima had the lowest (6.78) index (Table 2). Also, the results showed that the highest chlorophyll index (9.62) was obtained from 704 corn cultivars under a 100% irrigation regime whereas Maxima under 60% irrigation regime had the lowest (6.00) index (Table 3). Cultivar, irrigation and their interaction did not affect the chlorophyll index of sorghum at a 5% probability level (Table 4). Means comparison results also did not show any significant effect ($p>0.05$) of treatments (Tables 5 and 6).

Table 3. Mean comparison results of interaction effects of cultivar and irrigation on some morphological and biochemical traits in corn plants

Cultivar	Irrigation regimes (%)	grain yield (kg/ha)	harvest index (%)	grain fat (%)	grain lignin (%)	Chlorophyll index (spad)	Plant height (cm)	1000 grains weight (gr)
Maxima	100	1970.33[a]	13.08[a]	3.25[a]	1.92[c]	7.65[abc]	209.67[ab]	294.55[a]
	80	1218.60[a]	6.24[a]	3.07[a]	2.62[b]	6.70[bc]	197.67[b]	276.63[a]
	60	918.50[a]	5.79[a]	2.38[a]	2.70[b]	6.00[c]	176.67[c]	276.38[a]
704	100	3367.80[a]	18.54[a]	3.31[a]	2.72[b]	9.62[a]	218.60[a]	298.2[a]
	80	2045.37[a]	12.88[a]	3.16[a]	3.37[a]	9.26[ab]	199.53[b]	296.9[a]
	60	1086.57[a]	7.25[a]	2.62[a]	3.50[a]	6.89[abc]	166.33[c]	292.18[a]

The difference of numbers with at least one common letter in each column is not significant at the 5% level according to Duncan's test.

The chlorophyll index of leaves is a valuable index for evaluating photosynthetic activity and photo assimilates production (Alonso *et al*., 2002). According to the results, the chlorophyll index of Maxima under severe drought showed a significant decrease compared to 704 under average conditions. Drought stress has a direct effect on reducing the chlorophyll index of plant leaves (Nasrollahzadehasl *et al*., 2015). Decreased chlorophyll content under drought stress is probably due to the destruction of these pigments or t or their less production, as well as the dysfunction of the enzymes responsible for synthesizing this photosynthetic pigment (Erdem *et al*., 2006). The content of photosynthetic pigments, including chlorophylls and carotenoids, which are important for converting light energy into chemical energy, is affected by drought (Jaleel *et al*., 2009). These changes can cause limitations for photosynthesis, which complicates the evaluation of the direct effect of drought on stomatal closure, gas exchange and photosynthesis. The decrease in the concentration of chlorophylls and carotenoids in the first step is accompanied by the production of reactive oxygen molecules. Drought stress during the grain filling period induces the conversion of stem reserves into soluble sugars and their re-transfer to the grains by limiting water relations and photosynthesis (Blum, 2008).

Table 4. Variance analysis of cultivar and irrigation effects on some morphological and biochemical traits of sorghum

Sources of changes	d.f	average of squares						
		grain yield	harvest index	grain fat	grain lignin	Chlorophyll index	Plant height	1000 grains weight
Block	2	0.053 ns	0.028 ns	0.91 ns	0.10 ns	31.63ns	97.13 ns	0.08ns
Irrigation	2	0.103 ns	0.043 ns	0.06 ns	0.09 ns	14.76 ns	110.44ns	0.96 ns
Error A	4	0.015	0.017	0.22	0.19	9.87	55.39	1.04
cultivar	1	0.251*	0.617 **	1.19 ns	0.87 *	34.53ns	1330.42 ns	67.67 **
Irrigation × cultivar	2	0.003 ns	0.002 ns	0.06 ns	0.09 ns	3.68 ns	24.09ns	1.07 ns
Error b	6	0.026	0.010	0.28	0.10	23.72	71.18	1.96

ns non-significant, * and ** significant at 5 and 1 percent probability level, respectively.

Table 5. Mean comparison results of some sorghum's morphological and biochemical traits (simple effects of cultivar and irrigation)

	Treatment	grain yield (kg/ha)	harvest index (%)	grain fat (%)	grain lignin (%)	Chlorophyll index (spad)	Plant height (cm)	1000 grains weight (gr)
Irrigation regimes (%)	100	6475.00a	20.27a	2.70a	2.20a	25.79a	73.71a	37.42a
	80	5935.50a	19.80a	2.55a	2.11a	23.24a	73.00a	37.02a
	60	3772.83b	14.41a	2.74a	2.36a	22.93a	65.95a	36.62a
Cultivar	Payam	6650.89a	25.72a	2.41a	2.00b	22.60a	79.48a	35.08b
	Kimia	4138.00b	10.61b	2.92a	2.44a	25.37a	62.29b	38.96a

The difference of numbers with at least one common letter in each column is not significant at the 5% level according to Duncan's test.

Table 6. Mean comparison results of some sorghum's morphological and biochemical traits (interaction effects of cultivar and irrigation)

Cultivar	Irrigation regimes (%)	grain yield (kg/ha)	harvest index (%)	grain fat (%)	grain lignin (%)	Chlorophyll index (spad)	Plant height (cm)	1000 grains weight (gr)
Kimia	100	5463.67^{ab}	12.67^{c}	2.92^{a}	2.45^{a}	24.61^{a}	63.94^{b}	39.03^{a}
	80	4070.67^{ab}	11.20^{c}	2.92^{a}	2.29^{a}	20.99^{a}	63.27^{b}	38.8^{a}
	60	2879.67^{b}	7.95^{c}	2.92^{a}	2.59^{a}	22.21^{a}	59.67^{b}	39.03^{a}
Payam	100	7800.33^{a}	29.34^{a}	2.48^{a}	1.95^{a}	26.97^{a}	83.48^{a}	35.80^{b}
	80	7486.33^{a}	26.94^{ab}	2.18^{a}	1.93^{a}	25.49^{a}	82.74^{a}	35.23^{b}
	60	4666.00^{ab}	20.87^{b}	2.56^{a}	2.13^{a}	23.66^{a}	72.23^{ab}	34.20^{b}

The difference of numbers with at least one common letter in each column is not significant at the 5% level according to Duncan's test.

Drought stress decreased the amount of chlorophyll in corn leaves. The reason could be free radicals created during drought stress which caused the loss of chlorophyll. In general, lack of water causes damage to pigments and plastids, and drought stress limits plant photosynthesis by causing changes in the amount of chlorophyll and affecting photosynthetic components (Ahmad *et al*., 2015). On the other hand, the loss of chlorophyll under drought stress can have an adaptive aspect because by chlorophyll reduction, the amount of excited electrons during photosynthesis and then damage of free oxygen radicals is reduced (Adewale *et al*., 2018). Stone *et al*. (2001) also reported that receiving solar radiation due to chlorophyll reduction was one of the main factors in reducing corn grain yield under drought stress. Drought stress reduces the content of chlorophyll and the rate of photosynthesis.

Plant Height

Based on the results of Table (1), the effects of irrigation regimes and the interaction of irrigation and cultivar on corn's height was very significant ($p<0.01$). Corn height were decreased by increasing the drought stress. The highest plant heights (218.60 and 209.67 cm) were observed in 100% irrigation plus cultivars 704 and Maxima, respectively. The lowest amounts (166.33 and 176.67 cm) were observed in 60% irrigation plus 704 and Maxima cultivars, respectively. Also, a statistically significant difference was observed between the height of corn cultivars under 80 and 60 irrigation regimes (Table 3). The effect of cultivar treatment on sorghum height was significant at the 1% probability level (Table 4). Payam showed higher plant height than Kimia under different irrigation regimes (Table 5). A statistically significant difference was observed between Payam and Kimia cultivars under 100% and 80% irrigation regimes. So, under 100% and 80% irrigation regimes, Payam cultivar had the tallest plants (83.48 and 82.74 cm, respectively).

The lowest amount was obtained from Kimia (59.67, 63.27 and 63.94 cm) under 60, 80 and 100% irrigation regimes, respectively (Table 6). The height of plants is affected by genetic characteristics and environmental conditions such as humidity, light, nutrition, quantity and quality of light. Plant height is not an essential component of grain yield, but taller cultivars usually have higher biological yield (Agrawal *et al*., 2016).

It seems that competition between plants to obtain water under drought stress has resulted in a decrease in the allocation of photoassimilates to the stem, which led to shorter plants (He *et al*., 2017). Mir-Hosseni-Dehabadi (1994) stated that plants under severe drought stress had smaller plant height than control treatment and the growth of their stems was also slower. The reason was less metabolism and less leaf area per stem length unit. According to the results, shorter corn and sorghum plants under water stress can be attributed to the shorter internodes, reduced turgor pressure of the stomatal protective cells, impaired photosynthetic activities, impaired transfer of materials to different organs and decreased cell division (Farhad, 2011).

Probably, drought stress leads to a smaller leaves and shorter plants through the reduction of relative water content, followed by stomata closure and reduced growth and cell size (Ayana, 2011). In addition, the nutrients that plants absorb from the soil are soluble in water. Therefore, the limitation of water resources leads to limited food resources and plant is forced to reduce the growth and length of various organs, including plant height (Sangakkara *et al*., 2010). Cultivars with higher plant height can close their canopy earlier and prevent the light from reaching the bottom of the canopy. They will also produce more vegetative material due to having more shoots and increased size of physiological origin (Paolo and Rinaldi, 2008).

On the other hand, decreased height as a result of drought stress can be due to the effect of stress on cell growth and also less cell proliferation. Different varieties are different in terms of reaction to drought stress. Different varieties react differently to drought stress. In this regard, Nazarli and Zardashti (2010) stated that a minimum water potential was needed for cell elongation, and therefore, lack of water ultimately causes short internodes and stem. Apical meristems of stem increase the height or length of the plant, and under drought stress, meristem cells are less produced and as a result, the height will be decreased (Hajhassani Asl *et al*., 2011).

Khazaei *et al*. (2015) stated that the effect of irrigation on the height of sorghum was significant, so the maximum height was obtained from optimal irrigation and the height of the plant was reduced by applying drought stress during the growth stages of the plant. Khaton *et al*. (2016) have pointed out the decrease in plant height of different sorghum hybrids. The increase in plant height was also reported by Rabbani and Imam (2018) as a result of reducing the intensity of drought stress.

The results of this research are consistent with the reports of Hirich *et al*. (2012) and Arefi and Faraj-zadeh (2017), who reported that water deficiency decreased the height of corn plants.

1000 Grains Weight

According to the results of variance analysis of the data, irrigation, cultivar and their interaction did not affect the 1000 grains weight of corn significantly (Table 1). Mean comparison results also showed no statistically significant difference between different irrigation regimes and different cultivars (Table 3). The effect of cultivar treatment on 1000 grains weight of sorghum plant was highly significant ($p<0.01$) (Table 4). Mean comparison results showed significant differences between Payam and Kimia cultivars under various irrigation regimes and Kimia showed the highest 1000 grains weight under different irrigation regimes (Figure 6). Also, Kimia showed more 1000 grains weight (38.96 g) than Payam (35.08 g) (Table 5). This trait indicates the state and length of the reproductive period of the plant, when flowering begins and the number of grains is determined and seeds begin to receive and store photosynthetic materials. Also, grain weight depends on the position of floret on the panicle, cultivar and environment, all three of which are effective on grain weight through durability and rate of grain filling (Karami *et al*., 2011).

CONCLUSION

In general, tolerance to drought stress was different among sorghum and corn cultivars. Various cultivars showed different reactions to drought stress, which seem to have dissimilar mechanisms to tolerate drought stress. According to the results, sorghum has a qualitatively better performance under drought stress compared to corn. Also, Payam cultivar had a higher grain yield compared to Kimia. The higher grain yield of these cultivars is due to higher number of grains and grain weight in their clusters. This cultivar has kept its green leaves longer after grain formation, which is one of the reasons for high photosynthesis and higher grain yield in this cultivar. Corn grain fat was significantly superior to sorghum under drought stress. Sorghum also showed significant superiority in grain yield and harvest index under drought stress. These traits can be used as selection criteria to screen genotypes for drought stress tolerance. It seems that the biochemical characteristics of plants can be evaluated as stress resistance indicators in breeding programs. A better understanding of genetic resources (germ-plasm) diversity will improve their maintenance and preservation, their use and selection. Also, the use of locally adapted cultivars plays an important role in improving new cultivars and sustainable agriculture. A detailed diversity assessment of basic genetic resources provides the appropriate design and planning for the improvement of a crop plant with long-term goals and based on sustainable agriculture.

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