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The effect of irrigation-off stress on yield and yield components of grain sorghum cultivars

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Key words: Irrigation-off stress, grain sorghum, grain yield, yield components.

Abstract

In order to study the effect of irrigation-off on growth and yield of grain sorghum cultivars, a split plot experiment was carried out as randomized complete block design with three replications in the summer of 2012. Irrigation treatments included full irrigation based on 60 mm evaporation from class A evaporation pan (I_0), irrigation-off ate reproductive stage (I_1), irrigation-off at flowering stage(I_2), irrigation-off at grain filling stage(I_3) in main plots, and sop plot included grain sorghum cultivars (Payam, KGS36).The measured traits included number of grains per Ear, 1000-grain weight, grain yield, biological yield, and harvest index. The highest grain yield (394.45 g/m^2) and biological yield (1066.64 g/m^2) were obtained in full irrigation (control) and grain yield and biological yield in deficit irrigation treatment at flowering stage respectively decreased 46.8% and 12.5% compared with the control. The highest grain yield belonged to KGS36 cultivar by 510.53 g/m^2). The interactive effect of experimental treatments showed that the highest grain yield by 440.98 g/m^2 belonged to the treatment with full irrigation and KGS36 cultivar. KGS36 cultivar had the highest grain yield in two favorable and deficit irrigation conditions. Therefore, in deficit irrigation conditions it is possible to achieve acceptable yield by growing this cultivar

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Introduction

Crops yield is affected by environmental conditions, genetic structure and their interactive effect. Even though all direct and indirect stressful factors are considered as the important factors that reduce production (Entz, 1990), deficit irrigation stress is one of the most important factors restricting sorghum production in arid and semiarid areas. The decrease of grain sorghum yield under drought stress conditions depends on several factors such as plant development stage, severity and duration of water shortage and hybrids sensitivity (Frederick, 1990). Special morphological and physiological characteristics of this plant have caused it to be introduced as the indicator of drought resistant crops. Sorghum needs less water than other crops in order to grow and develop and have high and reliable yield even in harsh conditions. Sorghum is a yearling crop from grains family and has different types such as forage and grain cultivars. It is compatible with a wide range of ecological and farming conditions and while humidity, temperature, and nutrients can be limiting factors for the growth of other crops it have an appropriate yield (Karimi, 1997). Farming factors should be considered while selecting a grain sorghum cultivar for planting in an area. The product or yield is often the first factor which is considered as selection criterion' however, physiological maturity time, stalk strength and resistance to diseases are important factors considered in selecting the cultivar. A late-maturing cultivar in equal and good growth conditions will have more appropriate product than an early-maturing one (Anonymous, 2006). A cluster of sorghum usually contains 800 to 3000 grains. Grain size is different not only in various cultivars but also in the same cultivar which grows in different areas and seasons (Lee *et al.,* 2002). This experiment was carried put to investigate the response of sorghum cultivars to different levels of irrigation-off and to determine the sorghum cultivar that tolerates deficit irrigation stress in Khuzestan and also to examine the effect of irrigation-off and drought stress on different sorghum cultivars in a special stage of growth and development in order to study 1000-grain weight, number of grains per ear, grain yield, biological yield, and harvest index.

Materials and methods

Geographic Specifications of Experiment Location

This research was carried out in the research station of Shahid Salami in Ahvaz as a split plot experiment in the form of randomized complete block design with three replications. Experiment factors included four irrigation levels (irrigation-off at flowering stage, irrigation-off at reproductive stage, irrigation-off at grain filling stage, and full irrigation) in main plots and two sorghum cultivars (Payam, KGS36) in sub plots. Land preparing operation was done at the end of July. Sowing was done on August 6 as one-way cultivation next to back furrows. The space between plants was 12 cm. In each hole, 2-3 seeds were sown at a depth of 3-4 cm. Table 1. Physical and chemical characteristics of the soil of experiment location.

All plots were irrigated after planting but the next irrigations were done in proportion to related treatments. During the experiment, the weeds in the field were cut manually several times. A sample of compound soil was prepared and sent to the laboratory in order to determine its elements(Table 1).

According to soil experiment (phosphorus and potassium), before sowing 250 kg triple phosphate and 150 kg potassium and 180 kg nitrogen from urea source were added to the land once at the beginning of planting and once as excess. At physiological maturity stage, the crop was harvested manually from the halfway of two middle lines in an area of 1.5 m^2 and by omitting the margins and then biological yield and grain yield were measured. Moreover, 10 plants from each plot were randomly selected, and the number of grains per ears and 1000-grain weight were calculated. Then, variance of obtained data was analyzed by means of SAS software and the means of studied traits were compared via Duncan's multi range test at 5% level.

Results and discussion

1000-Grain Weight

The ANOVA results showed that 1000-grain weight was significantly affected by irrigation-off at 5% level and also by cultivar at 1% level (Table 2). The interactive effect of irrigation-off and cultivar was not significant.

Comparison of the means via Duncan's test at 5% level showed that the highest weight of 10000-grain by 25.12 g belonged to full irrigation treatment (I_0) and the lowest 1000-grain weight by 21.30 g belonged to treatment of irrigation-off at grain filling stage (I_3) which was not significantly different from irrigation-off at flowering stage (I_2).(fig.1) However, there was a significant difference between full irrigation treatment (control) and irrigation-off treatments at flowering stage and grain filling stage at 5% level.

Table 1. Physical and chemical characteristics of the soil of experiment location.

pH	Soil type	Percentage of soil components			Absorbable elements (ppm)			Soil depth (cm)
		Sand	Silt	Clay	K	P	N	
7/8	Clay loam	41	16	45	120/12	9/2	5/78	0-30
8/1	Clay loam	42	15	44	91/14	7/1	3/99	30-60

Vaezi Rad *et al.,* (2008) got similarresults reflecting the decrease of 1000-grain weight affected by water stress at grain filling stage. Emam*et al.,* (2007) stated that drought stress at flowering stage dramatically reduced 1000-grain weight and the highest decrease of grain yield was due to the decrease of 1000-grain weight. KGS36 cultivar by 24.80 g and Payam cultivar by 21.63 g product the highest and the lowest weight of 1000-grain, respectively (fig.2).

Table 2. ANOVA results of yield and yield components of grain sorghum.

		Mean of square				
S.o.v	df	Number of grains per ear	1000 grain weight	Grain yield	Biological yield	Harvest index
Replication(R)	2	75071	1.993	3003.9	27219	40.31
Irrigation (I)	3	460389**	33.9*	36549.5**	122501**	240.5*
Ea	6	33812	5.947	1908.5	7935	32.74
Cultivar(V)	1	460665*	60.357**	8584**	127873**	12.28n.s
Irrigation ×Cultivar (I×V)	3	57734*	1.972n.s	4832*	2183n.s	31.00n.s
Eb	8	9086	1.028	788.3	5023	15.36
(CV)	-	8.16	2.12	9.49	7.24	6.27

Ns: non-significant *: significant at 5% level and **: significant at 1% level.

Number of Grains per Ear

The ANOVA results showed that the number of grains per ear was significantly affected by irrigation-off at 5% probability level and also by cultivar at 1% level. The interactive effect of irrigation-off and cultivar at 5% level was significant, too (Table 2). There was a significant difference between different irrigation-off treatments at 1% level in terms of the number of grains per ear so that full irrigation treatment (I_0) by 14449.64 grains per ear and irrigation-off treatment at flowering stage (I_2) by 885.01 grains per ear had the highest and the lowest number of grains per ear respectively.The lowest number of grains per ear due to drought stress could be related to the decrease of ear length and diameter. Shortage of soil moisture strongly influences the growth and development of reproductive organs and reduces the yield. Khadem (2008) in his study on corn reported that drought stress decreased the number of grains in corn.

Table 3. Mean comparison of interactive effects of different levels of irrigation-off and cultivar on grain yield , number of grains per ear in grain sorghum.

	Mean of squares		
Cultivar	Irrigatio-off	Number of grains per ear	Grain yield
V_1	I_0	1209.34c	347.92b
	I_1	925.71f	268.24e
	I_2	828.48g	205.94f
	I_3	119.72d	297.98d
V_2	I_0	1689.93a	440.98a
	I_1	1030.80c	264.38e
	I_2	941.53f	213.05f
	I_3	1559.33b	323.71c

Yazar*et al.,* (2002) stated that the number of grains per ear highly depends on moisture and the first effect of drought stress on grain yield is the decrease of grains number per ear. Grain losses are due to lack of simultaneous development of flowers, abnormal menu of embryo sac before pollination and lack of grain development after pollination and fertilization (Niehsen, 2002). There was a significant difference between Payam (V_1) and KGS36 (V_2) cultivars and these two cultivars had the lowest and the highest number of grains per ear by 1028.31 and 1305.40 grains per ear, respectively. This might be due to longer growth of KGS36 and its ability to produce longer ears with more grains than Payam cultivar. Examining the interactive effect of cultivar and irrigation-off showed that the highest number of grains per sorghum ear by 1689.93 belonged to full irrigation treatment (I_0) and KGS36 cultivar (V_2) and the lowest number of grains per sorghum ear by 828.48 belonged to irrigation-off treatment at flowering stage (I_2) and Payam cultivar (V_1). (fig.3).

Grain Yield

The ANOVA results showed that irrigation-off and type of cultivar had a significant effect on grain yield at 1% level while the interactive effect of irrigation-off and cultivar at 5% level was not significant (Table 2). Comparison of means via Duncan's test showed that there was a significant difference between irrigation-off treatments. The highest grain yield by 395.45 g/m² belonged to full irrigation treatment (I_0) and the lowest grain yield by 209.50 g/m² belonged to irrigation-off treatment at flowering stage. It can be inferred that irrigation-off at flowering stage has affected both the number of grains (due to the loss of fetus) and grain weight through decreasing grain filling stage and decreasing assimilates mobilization resulting from the decrease of water and photosynthesis and consequently has led to the decrease of grain weight and grain yield.

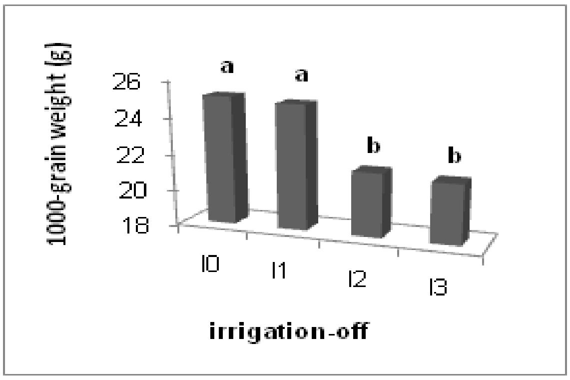

Fig.1. Effect of irrigation-off on 1000-grain weight.

Bonari*et al.,* (1992) stated that the occurrence of water limitation and drought stress would decrease the leaf activity and consequently would reduce plant yield. The reduction of grain yield in this stage is the decrease of the grain filling stage length and premature aging of the leaves. Kumari (1998) reported that drought stress would decrease the grain yield, number of grains per ear, and 100-grain weight in millet. Comparison of means via Duncan's test showed that there was a significant difference between different sorghum cultivars at 5% level in terms of their effect on grain yield, so that the highest grain yield by 310.53 g/m^2 belonged to KGS36 cultivar (V_2) and the lowest grain yield by 280.02 g/m^2 belonged to Payam cultivar (V_1). Investigating the integrative effect of cultivar and irrigation-off showed that the highest sorghum grain yield by 440.98 g/m^2 belonged to control treatment (I_0) and KGS336 cultivar (V_2) and the lowest grain yield by 205.94 g/m^2 belonged toirrigation-off treatment at flowering stage (I_2) and Payam cultivar (V_1).(fig.4).

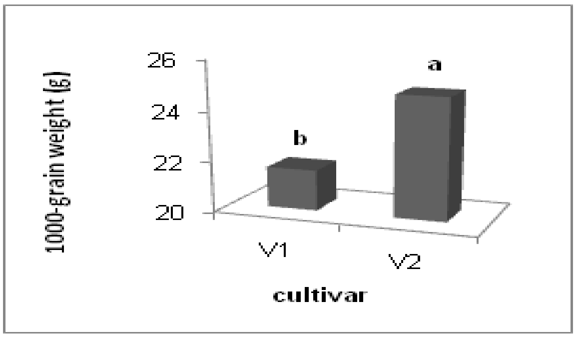

Fig. 2. Effect of cultivar on 1000-grain weight.

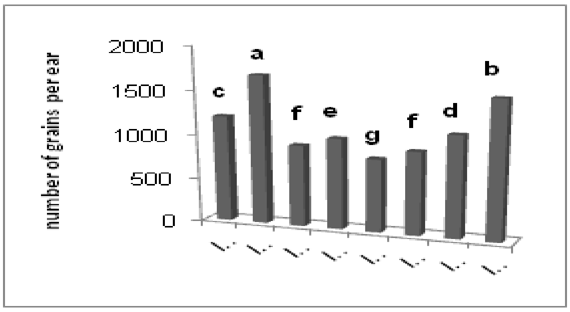

Fig. 3. Interactive effect of cultivar and irrigation-off on grain yield.

Biological yield

The ANOVA results showed that irrigation-off stress at different stages and type of cultivar had a significant effect on grain yield at 1% level while the interactive effect of irrigation-off and cultivar was not significant (Table 2).

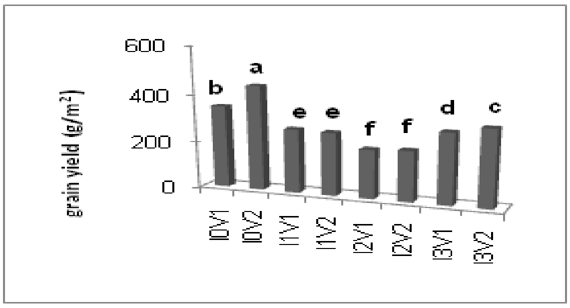

Fig. 4. The interactive effect of cultivar and irrigation-off on the number of grains per ear.

Comparison of means via Duncan's test showed that there was a significant difference between irrigation-off treatments at 5% level. The highest biological yield by 1066.64 g/m^2 belonged to full irrigation treatment (control) and the lowest biological yield by 933.52 g/m^2 belonged to irrigation-off treatment at flowering stage.(fig.5) This difference can be due to the decrease of cultivar ability in nutrition absorption and assimilates synthesis and mobilization because of lack of water which leads to the decrease of dry matter accumulation (Bayat*et al.,* 2010). The results of this part of experiment and in fact, the decrease of dry weight of shoots and the decrease of photosynthetic materials production due to water restriction were consistent with the findings of Bayat*et al.,* (2010) on wax bean. The increase of produced dry matter in plants under good irrigation conditions can be due to more spread of leaf area and its continuity, so that by creating efficient physiological source for maximum use of received light it has increased dry matter production. Biological yield was significantly different between two sorghum cultivars. KGS36 cultivar (V_2) had the highest biological yield by 1051.21 g/m^2 and Payam cultivar (V_1) had the lowest biological yield by 905.22 g/m$^{2.}$ (fig.6).

Harvest Index

The ANOVA results showed that harvest index was significantly affected by irrigation-off at 5% probability level whiletheeffect of cultivar and the interactive effect of irrigation-off and cultivar on harvest index were not significant (Table 2).

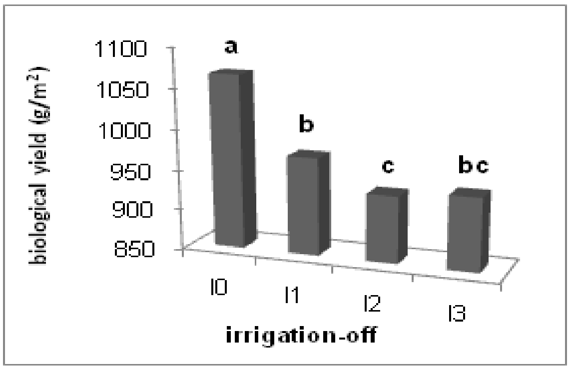

Fig. 5. The effect of irrigation-off on biological yield

Comparison of means via Duncan's test showed that there was a significant difference between different irrigation-off treatments in terms of their effect on harvest index at 5% level. The highest harvest index by 37.11% belonged to full irrigation treatment (I_0) and the lowest harvest index by 22.73% belonged to irrigation-off treatment at flowering stage (I_2).

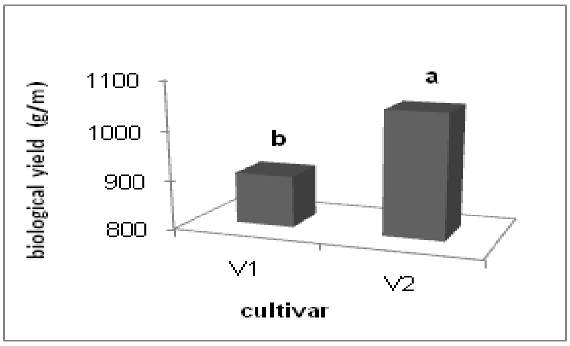

Fig. 6. The effect of cultivar on biological yield.

It might be due to the fact that inappropriate moisture conditions at flowering stage has caused an improper change of ratio of photosynthesis to respiration which in turn has led to the decrease of assimilates mobilization into grains. Mianab*et al.,* (2012) have attributed the decrease of harvest index at different stress levels to more reduction of grain yield in comparison to biological yield. They have reported that under stress conditions less assimilatesisallocated to the grains which leads to the decrease of grain yield and harvest index. Comparison of means showed that there was not a significant difference between cultivars in terms of harvest index. In this experiment, the highest percentage of harvest index by 30.92% belonged to KGS36 cultivar (V_2) and the lowest percentage by 29.49% belonged to Payam cultivar (V_1).(fig7) The harvest index indicatesthe percentage of transition of produced organic materials from origin to destination. KGS36 has higher percentage of harvest index and is able to carry more carbohydrates from green organs of plant to grains and lead to the increase of grain yield, but Payam cultivar has lower percentage of harvest index and is able to transfer fewer carbohydrates to grains and thus have lower grain yield. Therefore, it can be said that under similar environmental conditions for two cultivars, KGS36 cultivar is more successful than Payam cultivar in mobilizing synthetic materials from source to destination and has the highest percentage of harvest index.

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