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Halt Irrigation and Red Bean (*Phaseolus vulgaris* L.) Cultivars Responses

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Abstract: *Water deficit and drought stress consequently of its negative effects on plant growth stages as one of the main problems is agricultural of Iran. For this purpose, an experiment was carried out to evaluate the effect of halt irrigation on seed yield and some physiological characteristics of different red bean cultivars (*Phaseolus vulgaris *L.), based on split plot in a randomized complete block design with three replications during two years of 2014-2015 at Arak, Iran. Halt irrigation treatment was in main plots by four levels of control (full irrigation), Halt irrigation at vegetative stage, flowering stage and seed filling stages. Also, Red bean cultivars were in sub plots, including Goli, D81083, Derakhshan and KS31169. Analysis of variance results showed effect of halt irrigation treatments was significant in biological yield, seed yield, harvest index, number of pods per plant, number of seeds per pod and 100 seed weight. Furthermore, Halt irrigation could be reduced seed yield from 2624.73 kg ha^{-1} in full irrigation to 1632.82, 1088.55 and 2301.85 kg ha^{-1} irrigation halt at vegetative growth, flowering and pod filling stages respectively. Halt irrigation at flowering stage could reduce the red bean seed yield more than 35% significantly.*

Keywords: *halt irrigation, common bean, seed yield, yield components*

INTRODUCTION

More than 60 percent of all agricultural production is suffering from drought stress (Graham and Ranalli, 1997; Grant, 2012; Naeem, 2013). Among the factors limiting the yield, water deficit accounted for the greatest share in loss of yield so that virtually reduce production by about 25 percent. Drought resistance is the relative yield of a cultivar compared with the other cultivars under drought conditions (Blum, 1988). Crops are facing always during his life to water stress but the main stages of development such as seed germination, seedling growth and flowering of the most critical stages of plant growth and damage caused by drought stress but the most critical stages of plant growth and consequently the damage caused by drought stress are seed germination, seedling growth and flowering (Jaleel et al., 2007).

The effects of drought depends severity, type and time of stress and stage of plant growth on the common bean (Muñoz-Perea et al., 2006; Szilagyi, 2003; Terán and Singh, 2002b). About two thirds of the common bean production in the world is done under drought conditions (Sinclair, 1986) Hence, both the quality and quantity of beans are affected by water deficit (Ramirez-Vallejo and Kelly, 1998). As a result, there is the need to increase and improve the drought tolerance of bean cultivars in which adaptive mechanism to cope with drought stress include traits such as root

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structure, growth habit, accelerated maturation, early flowering, shoots accumulation and remobilization of Assimilate efficient to grains help increase the harvest index is of particular importance (Rosales-Serna et al., 2004; Terán and Singh, 2002a). Severe water deficiency in vegetative stage is causing a delay in growth and cause non uniform growth. Drought is one of the important abiotic stresses that significant changes induction in physiological and biochemical characteristics of the plants (Zobayed et al., 2007). In legumes, the flowering and pod development stages are the most sensitive to drought. Water deficit by interfering with the normal metabolism of the plants during flowering and early pod filling will cause the greatest reduction in bean yield (Dubetz and Mahalle, 1969; Flores and Fernando, 1982; França et al., 2000; Molina et al., 2001; Pimentel et al., 1999; Robins and Domingo, 1956; Singh, 1995, 2007; Stoker, 1974). Expansion cell growth processes is one of the first affected by water deficit (Hsiao, 1973). It is recognized that reduced the relative water content of cells and this reduction in sensitive cultivars was greater than resistant cultivars during drought stress (Chandrasekar et al., 2000; DaCosta et al., 2004; Lawlor and Cornic, 2002; Ma et al., 2006).

The researchers by reaction mung bean and common bean cultivars concluded that can be as an instrument for screening drought resistant cultivars beans to be used from physiological traits for drought tolerance (De Carvalho et al., 1998).

The main effect of drought stress on plant morphology, reduced in size. Loss of photosynthesis one of the most important factors in reducing the size of the plant and biomass production (Shao et al., 2008; Zare et al., 2011; Farooq et al. 2009) in this case, the total dry matter considerably reduced (Akhtar and Nazir 2013; Jaleel et al., 2009; Salehi-Lisar and Bakhshayeshan-Agdam, 2016). Therefore, the analysis of yield and biomass can be achieved effective results in different cultivars under water deficit. This process acts as a survival tactic, reduced water use efficiency and delaying the onset of stress is more severe, but generally irreversible. This study was performed aimed to determine the best cultivars for planting in water restrictions areas and also were assessed the most sensitive phonological stages on water deficit condition.

MATERIALS AND METHODS

This study was carried out at two years of 2014 and 2015 at Arak, agricultural research center, Arak, Iran (49°48' E, 34°3' N with an altitude of 1698.4 m above the sea level). Table 1 show summarizes the status of regional climate experiments.

The experiment was conducted as split plot in a randomized complete block design with three replications. Halt irrigation was in main plots by four levels of control (full irrigation), Halt irrigation in vegetative stage, at flowering stage and pod filling stage and four red bean cultivars were in sub plots, including: Goli, D81083, Derakhshan and KS31169. The dimensions of each were considered 4 meters long and 3 meters wide experimental plots with 12 square meters. So that each plot contained six rows spaced 50 cm. Plant density were set of 40 plants per square meter for all the plots to identical. Weed control was done by manual weeding in different stages of growth and development of common

Table 1
Characteristics of the regional climate during growth season of red beans in two years of the study.

Month of year	*Precipitation (mm)*	*Temperature (°C)*	*Sunshine (h)*	*Precipitation (mm)*		*Temperature (°C)*		*Sunshine (h)*	
	The average 50 year			*2014*	*2015*	*2014*	*2015*	*2014*	*2015*
June	2.8	24	345	0	0	25.9	28.3	323.1	317.2
July	1.2	27.3	334.8	1	1.8	29	29.9	369.2	358.1
August	1.6	26.4	330.9	0	0	27.7	23.1	306.1	306.5
September	0.9	21.9	305.1	0	0	23.6	17.3	310	300.5

beans. To determine the seed yield at physiological maturity were harvested by considering the margins of each experimental unit all plants in the two square meters of the central rows of each plot. Then were determined the biomass and seed yield.

The following formula was used to measure the harvest index (Beebe et al. 2010).:

$$HI = GY/BY*100$$

To determine the relative water content from the youngest leaves developed and tension in the peak hour were selected of each variety in each replication. After cutting the leaves were placed in a ice flask and immediately transported to the laboratory. Fresh weight determined in the laboratory and then leaves in distilled water for 24 hours at room temperature in the darkness and ensuing saturated weight was determined, then the leaves are placed for 24 hours at 70°C oven and dried. Leaf RWC was obtained by the following formula (Barrs, 1968). In this formula, was considered fresh weight (FW), saturated weight (SW), dry weight (DW).

$$RWC= FW-DW/SW-DW*100$$

In order to measure the number of pods per plant and seeds per pod of ten plants per plot was carried out randomly selected and measurements (Beebe et al. 2008). Also to calculate the 100 seed weight, number of seed per ten samples from each plot were counted and the weight of each sample was determined with an exact weighing scales. To determine the seed proteins, initially mills part of the seeds from each plot and then protein content was measured to the Kjeldahl method. Crude protein concentration was estimated by applying the factor N×6.25 to the total nitrogen content determined after mineralization (350°C during 8 h) of dry ground seeds with sulfuric acid and 5% salicylic acid added, according to the calorimetric method of Berthelot modified by Mann (1963).

Analysis of variance and mean comparison was conducted software MSTAT-C and mean comparisons using LSD test at the level of 5% statistical probability.

RESULTS AND DISCUSSION

Seed yield

The results showed that the effect of different halt irrigation and red bean cultivars on seed yield was significant (1%) (Table 2). Derakhshan bean had the highest yield in full irrigation and the highest seed yield was significantly different when halt irrigation treatments was applied (Table 3).

Table 2
Analysis of variance of halt Irrigation and cultivars on yield and yield components.

Source of variation	*d.f.*	*Mean squares*							
		Seed yield	*Biological yield*	*Harvest index*	*Number of pods per plant*	*Number of seeds per pod*	*100-seed weight*	*Protein content*	*RWC*
Year (Y)	1	2422n.s	617442n.s	23.91n.s	0.33n.s	0.01n.s	0.31n.s	0.22n.s	94.49n.s
Year×Rep	4	210576	1276303	21.69	20.28	0.60	19.35	18.00	30.36
HaltIrrigation(I)	3	11327880**	9836039**	2319.70**	86.60**	3.93**	70.93**	93.51**	1249.43**
Y×I	3	15603n.s	249400n.s	20.05n.s	0.34n.s	0.01n.s	0.63n.s	0.51n.s	454.63**
Erorr I	6	18189	572932	20.22	4.40	0.19	0.59	3.91	48.90
Cultivars (C)	3	1707335**	9084046**	124.94**	68.97**	2.10**	439.49**	76.80**	728.36**
C × Y	3	284420**	987219*	57.34**	0.45n.s	0.16n.s	9.02**	0.31n.s	312.90**
C × I	9	348707**	6136178**	54.37**	14.63**	0.34n.s	9.25**	0.79n.s	102.12**
C × I × Y	9	46838n.s	433154n.s	13.21n.s	0.24n.s	0.13n.s	0.32n.s	0.04n.s	66.70**
Erorr C	54	45021	287699	11.34	3.44	0.17	2.06	1.19	15.88
CV%		11.10	9.65	9.88	23.18	15.25	5.47	5.66	6.16

n.s, * and ** are non-significant, significant at the 5% and 1% levels of probability, respectively.

In this study the interaction between treatments was affected by produce the highest seed yield by 3021.4 kg.ha^{-1}, when full irrigation was applied in Derakhshan cultivar. Means, the 73.25% greater than halt irrigation at flowering stage in Goli.

Other studies have shown the greatest reduction in seed yield occurred at the drought stress in flowering stage, after in vegetative stage and end of the pod filling (Araújo and Teixeira 2008; Ghanbari et al. 2013; Muuhouche et al., 1998; Rauthan and Schnitzer 1981).

Furthermore, the irrigation for two weeks at flowering or podding or pod filling can reduce seed yield (Rezaei and Kamkar-Haghighi, 2009).

Table 3
Means comparison of yield and yield components of red been for treatments.

	Treatments	*Seed yield (kg ha^{-1})*	*Biological yield (kg ha^{-1})*	*Harvest index (%)*	*Number of pods per plant*	*Number of seeds per pod*	*100-seed weight (g)*	*Protein content (%)*	*RWC (%)*
Halt irrigation	I_1 (Control)	2624.73	5779.00	46.04	9.98	3.14	28.01	21.38	72.46
	I_2 (Vegetative)	1632.82	5217.20	31.24	7.79	2.76	26.71	18.93	66.48
	I_3 (Flowering)	1088.55	4887.80	22.56	5.49	2.18	23.90	16.70	55.07
	I_4 (Pod filling)	2301.85	6342.50	36.55	8.74	2.87	26.33	19.98	64.75
LSDi		114.76	458.80	4.11	0.53	0.09	0.73	0.66	19.59
Cultivars	C_1 (Goli)	1897.20	5536.80	32.59	10.02	2.68	21.61	19.10	66.86
	C_2 (D81083)	1719.40	4948.80	35.52	8.48	2.40	28.47	18.43	56.70
	C_3 (Derakhshan)	2293.70	6403.70	36.51	7.52	2.77	31.02	21.78	65.92
	C_4 (KS31169)	1737.60	5337.10	31.75	5.98	3.12	23.85	17.66	69.28
LSDc		489.95	912.80	6.96	0.62	0.37	2.76	0.51	16.25

Different letters within each column indicate significant difference using LSD test at pd”0.05.

Table 4
Means comparison of yield and yield components of red been for interaction of treatments.

Treatment	*Seed yield (kg ha^{-1})*	*Biological yield (kg ha^{-1})*	*Harvest index (%)*	*Number of pods per plant*	*Number of seeds per pod*	*100-seed weight (g)*	*Protein content (%)*	*RWC (%)*
I_1C_1	2942.90	6956.90	42.33	14.90	3.23	22.72	21.30	75.85
I_1C_2	2185.40	4451.30	49.84	9.35	2.94	29.32	20.35	60.92
I_1C_3	3021.40	5836.00	52.10	8.05	3.31	33.13	23.80	73.55
I_1C_4	2349.30	5871.80	39.88	7.60	3.10	26.89	20.05	79.52
I_2C_1	1374.30	4426.10	31.15	7.99	2.51	22.55	18.91	69.78
I_2C_2	1377.00	4601.10	30.05	9.59	2.51	28.26	17.96	55.04
I_2C_3	2098.60	6302.20	33.54	7.94	2.80	30.68	21.41	67.66
I_2C_4	1681.40	5539.50	30.21	5.63	3.22	25.33	17.45	73.46
I_3C_1	808.20	3385.50	23.56	5.97	1.97	18.86	16.28	53.77
I_3C_2	1173.00	5085.00	23.49	6.32	1.73	26.29	16.48	55.27
I_3C_3	1401.10	6747.10	20.80	5.22	2.31	30.17	19.51	57.13
I_3C_4	971.90	4333.50	22.38	4.43	2.73	20.27	14.51	54.11
I_4C_1	2463.20	7378.60	33.33	11.20	3.01	22.31	19.91	68.03
I_4C_2	2142.40	5658.00	38.71	8.64	2.42	30.02	18.96	55.60
I_4C_3	2653.80	6729.50	39.61	8.88	2.64	30.09	22.41	65.35
I_4C_4	1948.00	5603.70	34.55	6.23	3.43	22.93	18.65	70.03
LSD	282.66	859.57	4.75	0.65	0.48	0.74	0.25	10.67

Different letters within each column indicate significant difference using LSD test at $p \leq 0.05$.

In this study, all red bean cultivars were the loss yield when halt irrigation were applied in flowering stage as the most critical phase. But, in Derakhshan cultivar we sow the the lowest reduction in seed yield by 1401.10 kg.ha^{-1}.

In D81083 about 1173.00 kg.ha^{-1}, KS31169 , 971.90 kg.ha^{-1} and Goli by 808.20 kg.ha^{-1} the largest reduce in seed yields than to the control was measured.

Biological yield

Combime analysis of variance results for biological yield showed that the weather conditions (year) had not significant effect. But, the effects of halt irrigation on red bean cultivars had significant effects at the 1% level on biological yield. The interaction effect of halt irrigation and cultivars on biological yield were significant too (Table 2).

Mean comparison of the interaction effect of halt irrigation and cultivars showed that the highest biological yield was obtain in KS31169 cultivar with full irrigation by 7378.60 kg.ha^{-1} (Table 4). Which can be shows the important effect of biological yield on yield under drought stress.

In reportes came the drought stresses reduces biomass and seed yield From 20 to 90% (Nuñez Barrios et al., 2005) and remaining days to maturity (Muñoz-Perea et al., 2005).

Drought stress although, reduced the biomass, grain yield, harvest index and the seed weight too (Muñoz-Perea et al., 2006).

Harvesting index

Different level of halt irrigation and cultivars treatments had significant effects on harvesting index (Table 2). Harvesting index value in Derakhshan cultivar with 36.51% was higher than those other common beans cultivars. Moreover, the reduction in harvest index by halt irrigation at flowering stage was 51% reduce compared to control (Table 3).

the interactions effect between treatments were found for made the highest harvesting index by 52.10% in Derakhshan under full irrigation meaning of 60% greater than the amount of harvest index in halt irrigation at flowering stage to 20.80% with same cultivar via. Derakhshan.

We can mention however Derakhshan cultivar had the highest harvesting index but also has been the most drop in HI at critical condition (Table 4). That's mean it is a sensitive cultivar to scarcity of water.

The higher harvest index due more to water deficit can be power of transferred from assimilates to the pod and thus increase the seed yield. Water stress could be decrease the harvest indexin common beans too (Acosta-Gallegos and Adams 1991; Ramirez-Vallejo and Kelly 1998; Bashteni, 1997; Taleie et al., 2001).

Number of pods per plant

The results showed that the effect of halt irrigation and cultivars on the number of pods per plant were significant (Table 2). Goli cultivar had higher number of pods per plant than those other cultivars. Mean comparison of halt irrigation showed that the highest number of pods per plant belonged to full irrigation with 9.98 and the lowest number belonged to the halt irrigation in flowering stage with 5.49 (Table 3). The highest number of pods per plant was belonged to control and Goli with 14.90 and the lowest as to halt irrigation in flowering stage and KS31169 with 4.43. Yield increases with the increasing number of pods and higher yield has been during drought resistant varieties are more pods (Turk, Hall, and Asbell 1980). According to the opinion of many research Among yield components, number of pods per plant was the most important trait in determining the bean yield and the highest correlation with grain yield (Bayat et al., 2010; Khoshvaghti, 2006).

Number of seeds per pod

Analysis of variance results showed that the effects of halt irrigation and red bean cultivars on biological yield was significant at the 1% level but the interaction effect of halt irrigation and red bean cultivars on biological yield was not significant (Table 2).

According and emphasis to the previous results the lowest number of seeds per pod was due to halt irrigation with 2.18, the highest and lowest respectively with 3.12 at KS31169 and 2.40 at D81083 (Table 3).

The number of seeds per pod determines the plant storage capacity. In other words, the higher number of seeds as the plant storage is larger for assimilate production and whatever factor increases this capability will in fact increase the yield (Bryan et al., 2001).

100-grain weight

the effect of halt irrigation and red bean cultivars and their interaction effect on 100-grain weight were significant (1%) as shown in Table 2. Derakhshan with 31.02g had a higher weight than those other cultivars. In examining the interaction effect of halt irrigation and cultivars, the highest weight of 100-grain belonged to full irrigation and Derakhshan with 33.13g and the lowest belonged to in halt irrigation at flowering stage and Goli with 18.86g (Table 4).

Generally lack of water in vegetative and reproductive stages was reduces seed weight with increased due to competition for water and nutrients in sinks. This could be due to reduce duration of vegetative and reproductive growth during moisture stress which shortens the effective grain filling period and to reduce manufacturing and assimilate translocation the seeds and reduced the seed weight (Saxena et al., 1993; Turk et al., 2004; Zhu, 2002). Drought stress also can be due to loss of vegetative and reproductive stages, reducing the remobilization of photosynthetic assimilates in grain filling stage (Gebeyehu, 2006; Khoshvaghti, 2006).

Protein content

protein content was significant affect by different halt irrigation in red bean cultivars (Table 2). Nevertheless, the highest amount of protein was obtain in Derakhshan cultivar by 23.80% in full irrigation condition and the lowest protein content was about 14.51% in KS31169 red bean in halt irrigation at flowering stage condition (Table 4). In legumes protein content decreased with increasing drought stress, but was more than The ratio of protein to starch (Ghanbari et al., 2013; McDonald, 1992). Research shows that protein synthesis mechanisms are more resistant to drought, which the most sensitive step is reproductive stage. So in drought conditions, more impressive decline is in the starch synthesis.

Relative Water Content (RWC)

effect of halt irrigation and cultivars treatments were significant effects on leaf relative water content in red bean cultivars (Table 2). While, the D81083 in normal irrigation showed the least amount of relative water content, but it was the lowest loss when used halt irrigation at flowering stage that is the most sensitive stage in dealing with water deficit.

After that, Derakhshan cultivar has the minimum rate of decline of RWC in leaf tissues. Derakhshan also, had the most better situation in this traites than other cultivars (Table 4). Under

Table 5
Correlation indices for yield and yield components of red been.

characteristics		*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*
1.	Seed yield	1.00							
2.	100 Seed weight	0.468**	1.00						
3.	Biomass yield	0.676**	0.339**	1.00					
4.	Harvest index %	0.810**	0.456**	0.146$^{n.s}$	1.00				
5.	No. pod per plant	0.595**	0.141$^{n.s}$	0.355**	0.496**	1.00			
6.	No. seed per pod	0.603**	0.110$^{n.s}$	0.369**	0.518**	0.303**	1.00		
7.	Protein content %	0.764**	0.572**	0.477**	0.672**	0.461**	0.326**	1.00	
8.	RWC %	0.465**	0.017$^{n.s}$	0.273**	0.394**	0.209*	0.431**	0.389**	1.00

ns, non-significant, *and ** significant at 0.05 and 0.01 probability level respectively.

drought condition maintained higher relative water content resistant varieties than susceptible and relative water content in these varieties will be considered as a mechanism for drought tolerance up to an escape mechanism that due to the higher osmotic adjustment or the whole, lower elasticity (Jiang & Huang, 2001;Rosales-Serna et al., 2004). Finally, all of the yield components, except 100-grain weight has a positive and significant correlation with yield (Table 5).

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