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Effect of straw mulch application on agronomic traits and grain yield of common bean (*Phaseolus vulgaris L.*) cultivars under drought stress

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Key words: Common bean, grain yield, agronomic traits, straw mulch, water deficit.

Abstract

In order to investigate the agronomic traits and grain yield of common bean *(Phaseolus vulgaris L.)* cultivars under irrigation and straw mulch treatments, an experiment was conducted as factorial based on randomized complete block design with three replications at the research farm of the Faculty of agriculture, University of Tabriz, Iran in 2012. Treatments were two irrigation levels (60 and 120 mm evaporation from class A pan), two cultivars with different growth habits (akhtar and naz as determinate and indeterminate respectively) and two mulch levels (0 and 2 ton/ha of wheat straw). Results showed that effect of irrigation levels, straw mulch and cultivars were significant on plant height, number of leaf per plant, relative water content (RWC) and grain yield of common been. Normal irrigation and application of straw mulch produced the highest measured traits. Also in normal irrigation, leaf area index (LAI) and chlorophyll contents were significantly increased. Akhtar cultivar had higher LAI than that of Naz. Straw mulch in both irrigation treatments improved agronomic traits and grain yield of common bean cultivars.

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Introduction

Common bean *(Phaseolus vulgaris)* is an important source of food throughout the world and contains protein, fiber and vitamins that increased food value of this product (Dursum, 2007). Different types of common bean by, 20-25% protein and annual production of more than 19.3 million tons are in the first place of pulses production (Anonymous, 2006). There are some reports that common bean is susceptible to drought stress and production of this crop in many regions of the world is carried out under drought stress conditions, due to insufficient water supply by rainfall and/or irrigation (Zlatev & Stoyanov, 2005; Machado & Durães, 2006).

Drought stress is one of the limiting factors in crop growth and yield which reduces dry matter production, grain yield and yield components through decreasing leaf area and accelerating leaf senescence (Emam & Seghatoleslami, 2005). Loss of leaf area, which could result from reduced size of younger leaves and inhibition of the expansion of developing foliage, is also considered an adaptation mechanism to drought (Gallegos & White, 1995). Emam et al. (2010) showed that plant height, number of leaves, leaf area, and number of pods, pod dry weight and total dry weight significantly respond to water stress conditions. Chlorophyll content which directly associated with biomass accumulation in bean decrease by water deficit (Rosales-Sernaet al. 2004).
Straw mulch ameliorates drought stress by reducing evaporation (E) from the soil and increasing infiltration rate (Lal, 1975). To tackle the problem of water loss by evaporation in dry land areas with water shortages and rainfall fluctuations, soil surface mulch with crop straw or plastic sheet has been widely practiced (Unger et al., 2012). In soil surface, covered with either plant residues or plastic sheets water loss by evaporation is greatly reduced (Pabin et al., 2003). As a direct result, mulching conserve the soil moisture during entire crop growth period, and provides the best opportunity for increasing crop productivity (Carter, 1998). Zhang *et al.* (2005) in northern China resulted that straw mulch reduce soil evaporation and increase plant water use efficiency. Another advantage of mulching is increasing of soil organic matter and nutrient supply. Straw mulching systems can conserve soil water and reduce soil temperature because they reduce soil disturbance and increase residue accumulation at the soil surface (Zhang et al., 2009).

The crop plants frequently suffer seasonal drought, therefore, attention is needed to be focused on enhancement of drought tolerance of crop plants. The present study was aimed to investigate the effects of different mulches and irrigation regimes on agronomic traits and grain yield of common bean.

Material and methods

A field experiment was conducted in 2012 at the research farm of the university of Tabriz, Iran (latitude 38°05_N, longitude 46°17_E, altitude 1360 m above sea level).The experiment was arranged as factorial based on randomized complete block design with three replications. The three factors were studied during the research included Irrigation as two irrigation levels (I_1 and I_2: 60 and 120 mm evaporation from class A pan, respectively), two cultivars with different growth habits (akhtar as a determinate and naz as an indeterminate cultivar) and two mulch levels including 0 (control) and 2 ton/ha wheat straw.

Each plot had 10 planting rows with 4m length and inter and intra space of 25 and 8 cm, respectively. Irrigation and straw mulch treatments were applied after seedling establishment. In pod filling stage all agronomic traits were determined. Leaf chlorophyll index was measured using the chlorophyll meter (MINOLTA, SPAD-502). RWC of the uppermost fully expanded leaflets was measured following Lopez et al. (2002). The leaflets were detached and weighed (fresh weight, FW), floated on water for 2 h (assuming that complete hydration of leaflets occurred within 2 h) to allow turgidity to be regained and then re-weighed (turgid weight, TW) and dried overnight at 80°C to determine the dry weight (DW).

The relative water content was calculated as follows:

RWC (%) = (FW-DW)/(TW-DW)×100

Grain yield at maturity stage was harvested from middle rows of each plot by considering marginal effect.

All the data were analyzed on the basis of the experimental design, using SAS (version 9.1) software. Means comparison was performed based on Duncan's multiple range test (P≤0.05). Excel software was used to draw figures.

Results and discussion

Irrigation treatment and wheat straw mulch had significantly effect on plant height, number of leaf per plant, relative water content (RWC) and grain yield. Leaf area index (LAI) and chlorophyll contents were also significantly affected by irrigation treatments. The effect of cultivar on plant height, number of leaf per plant, relative water content (RWC), leaf area index (LAI) and grain yield was significant. The interaction between irrigation × mulch and irrigation × cultivar on plant height, also interaction of between irrigation × mulch × cultivar on grain yield were significant (Table 1).

Table 1. Analysis of variance of agronomic traits and grain yield of common bean as affected by irrigation, straw mulch and cultivar treatments.

Source of variation	df	Plant height	Leaf number per plant	Relative water content	Leaf area index	Leaf chlorophyll index	Grain yield
Replication	2	0.63875	2.08	1.337	0.5	0.63791	935.489
Irrigation (I)	1	95.6004**	45.375**	2380.04**	3.9204**	30.6004**	2845715.093**
Mulch (M)	1	16.8337**	6.202*	220.826**	0.0937	0.40041	1138445.003**
I*M	1	11.9004**	2.94	61.44	0.5104	0.22041	6527.081
Cultivar (C)	1	415.833**	16.007**	105.001*	11.620**	9.25041	2236939.271**
I*C	1	13.0537**	0.202	39.015	0.1837	0.26041	53750.815**
M*C	1	0.00375	0.482	1.7066	0.0004	0.57041	139097.139**
I*M*C	1	0.84375	0.107	11.206	0.0037	0.02041	21853.321**
Error	14	1.2663	1.001	17.947	0.372	2.293	1773.727
CV%		3.55	6.15	6.63	14.48	4.17	5.46

* and ** , Significant at 5% and 1% probability level, respectively.

Table 2. The mean compassion of the main effect of irrigation, straw mulch and cultivars on agronomic traits.

Treatment	Plant height (cm)	Leaf number per plant	Relative water content (%)	Leaf area index	Leaf chlorophyll index (SPAD)
Irrigation					
I_1	33.63 a	17.6 a	73.76 a	4.61 a	37.43 a
I_2	29.64 b	14.9 b	53.85 b	3.8 b	35.17 b
Mulch					
Control	30.8 b	15.7 b	60.77 b	4.15 a	36.18 a
2 Ton/ha	32.47a	16.7 a	66.84a	4.27 a	36.49 a
Cultivars					
Akhtar	35.8 a	15.4 b	65.9 a	4.9 a	35.68 a
Naz	27.47b	17.1 a	61.71 b	3.51 b	36.92 a

The means with same letters in each column are not significantly different at p ≤ 0.05.

Akhtar had higher grain yield (Table 5.), plant height, RWC and LAI than that of Naz, but the highest number of leaf was recorded to Naz (Table 2.). Application of mulch was increased plant height of common bean cultivars in normal and water stress condition. As a result under water deficit condition, application of mulch caused the stability in plant height (Table 3.).

Table 3. Mean plant height of common bean under irrigation and wheat straw mulch treatments.

Irrigation	Mulch	Plant height (cm)
I_1	Control	33.50^a
I_1	2Ton/ha	33.70^a
I_2	Control	28.10^c
I_2	2Ton/ha	31.18^b

I1 and I2: Irrigation after 60 and 120 mm evaporation from class A pan, respectively.

Straw mulch potentially increased the soil moisture content which in turn led to improved growth. These results are in agreement with that of Ahmed et al. (2007) who reported that the increase in mulch rate from 1000 to 4000 kg ha^{-1} when compared with control progressively increased the plant height (10 to 37 %). Xue et al. (2013) also reported increase in plant height of soybean mulched with wheat straw, while lowest height was observed in the control. The increase in plant height could be attributed to moisture conservation and weed suppression due to the application of mulches (Ullah et al., 1998). Also plant height was significantly affected by interaction of irrigation × cultivar (Table 1.). Plant height of both cultivars was declined with increasing water stress but Akhtar had more height in comparison with Naz (Table 4.).

Table 4. Mean plant height of common bean cultivars under irrigation treatment.

Irrigation	Cultivar	Plant height (cm)
I_1	Akhtar	38.53^a
I_1	Naz	28.73^c
I_2	Akhtar	33.07^b
I_2	Naz	26.22^d

I_1 and I_2: Irrigation after 60 and 120 mm evaporation from class A pan, respectively.

This finding is in agreement with the results of Nielsen and Nelson, (1998) and Shenkut and Brick, (2003) whereas, they reported depression of plant height as a result of severe influence from environmental factors such as water stress. Plant height decreased under stress, however genotype can be affect this trait (Salhi et al., 2008).

Mulch application and normal irrigation (I_1) increased the number of leaf per plant (Table 2.). These results are also in accordance with Xue et al. (2013), who concluded that application of mulch at the rate of 11000 kg/ha enhanced the number of leaves by 136% against control. Wakrim et al. (2005) reported decreasing plant growth as one of the reasons for reduction of pod number per plant under drought stress conditions and decline in photosynthetic production.

Decreasing percentage for the plant height, number of leaf, RWC, LAI and grain yield in I_2 (120 mm evaporation from class A pan) related to I_1 (60 mm evaporation from class A pan) with application of 2 ton/ha wheat straw mulch were less in comparison with control (Fig. 1.).

Results indicated that water stress decreased RWC, but, application of straw mulch was improved that (Fig.1.). Khan et al. (2007) concluded that water deficit stress resulted in a considerable decline in RWC (18%; from 83% in normal condition to 68% in stressed plants). Nami et al. (2012) and Ghanbari et al. (2013) reported that the leaf RWC significantly decreased in common bean as water stress intensified during the growing season.

LAI was not significantly influenced by the straw mulch, however straw mulch showed relatively higher LAI than control (Fig. 1.). Water stress was significantly declined LAI. Markhart (1985) also found significant reductions in the leaf area under drought conditions at 23 days after planting for two bean species (*P. vulgaris* and *P. acutifolius*).

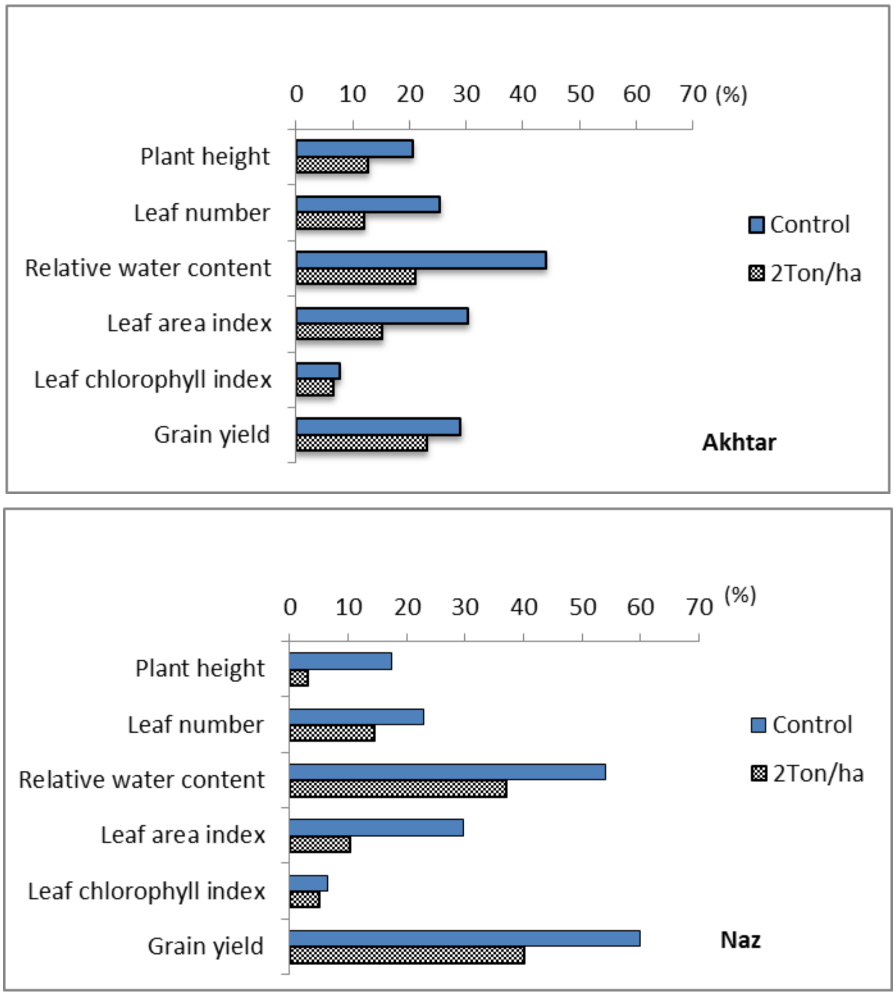

Fig. 1. Percent of decreased of for agronomic traits and grain yield of common bean cultivars in I2 (120 mm evaporation from class A pan) related to I1 (60 mm evaporation from class A pan) under control and straw mulch treatments.

Straw mulch had no significant effect on chlorophyll index, but the effect of irrigation on chlorophyll index was significant (Table 2.). Decrease in chlorophyll contents under water stress can be attributed to the sensitivity of pigments to increasing stress, which has been reported by Younis et al. (2000). Silva et al. (2007) reported that total chlorophyll contents decreased in sugarcane grown under soil water deficit conditions.

The effects of irrigation, mulch and cultivar on grain yield were significant (Table 1.). Also, grain yield was significantly affected by Interaction of irrigation × mulch × cultivar. The highest grain yield (3135.22 Kg/ha) was obtained in normal irrigation (I_1) treatment and application of 2 ton/ha mulch in Akhtar cultivar (Table 5.).

The observations revealed that application of straw mulch considerably increased grain yield over control (Table 5.). Likewise, straw mulch under water-limiting and well-watering conditions increased the grain yield by 29% and 17%, respectively. Increasing of grain yield under normal irrigation (I_1) treatment was mainly attributed to increasing plant height, number of leaf per plant, leaf chlorophyll index, RWC and LAI in this condition.

In sever water stress condition loss of grain yield of Naz cultivar was higher than that of Akhtar. Mulch application in water stress condition was improved grain yield of Naz and loss of grain yield of this cultivar in comparison to Akhtar was significantly reduced. In contrast, application of mulch in well-watering condition had higher effect on Akhtar than that of Naz.

These results are in accordance with Liang et al. (1999) who reported that mulching treatment could effectively retain soil moisture and improve nutrient transformations and availability, thus ultimately improve grain yield. Grain yield under mulching was higher due to longer rooting and higher moisture content in the upper soil layers (Bonfil et al. 1999). Yang et al. (2006) reported that increase in grain yield could be attributed to increased photosynthesis in wheat with straw mulching. Similar findings have also been reported by Qin et al. (2010) who reported the enhanced yield in rice by straw mulching. Results of this research indicated that all agronomic traits and grain yield of common bean was obviously greater in straw mulch treatments than in the control treatment, indicating that application of wheat straw mulch could be increase the tolerance of common bean plants to drought stress.

Table 5. The mean compassion of the main effect of irrigation, straw mulch and cultivars on grain yield.

Treatments			Grain yield (Kg /ha)
Irrigatin	Mulch	Cultivar	
I1	Control	Akhtar	2520.00[b]
		Naz	2216.66[d]
	2Ton/ha	Akhtar	3135.22[a]
		Naz	2406.66[c]
I2	Control	Akhtar	1953.33[e]
		Naz	1340.00[g]
	2Ton/ha	Akhtar	2513.81[b]
		Naz	1716.66[f]

I1 and I2: Irrigation after 60 and 120 mm evaporation from class A pan, respectively.

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