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Effect of plant density and different irrigation strategieson crop yield and canopy cover of red beans, *Phaseolusvulgaris* L. cv. Akhtar

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ABSTRACT- In order to study the effects of different irrigation regimes and plant density on yield and yield components of bean, a split plot arrangement was conducted in complete randomized block design during two years. The foremost variable was four levels of irrigation: 60, 80, 100, and 120% of the potential evapotranspiration. The second variable was within the row spacing of 5 cm (D1), 10 cm (D2) and 15 cm (D3) in three replications. The dry biomass and yield of bean were shown to be significantly affected by the difference within row spacing and irrigation. Results indicated that the dry biomass and grain yield increased when the density of planting and irrigation increased. In 2013, the maximum yield was 3061.8 kg ha^{-1}, occurring at 120% of potential evapotranspiration and the 5 cm within row spacing. The maximum water use efficiency was 0.33 kg m^{-3}, occurring at 100% of potential evapotranspiration and the 5 cm within row spacing. Minimum yield and water use efficiency under the condition of 60% potential evapotranspiration and within row spacing of 15 cm were 834.2 kg ha^{-1} and0.12 kg m^{-3}, respectively. With respect to 100% potential evapotranspiration and within row spacing of 5 cm in 2014, the maximum yield and water use efficiency were 3305.2 kg ha^{-1} and 0.34 kg m^{-3}, respectively. Minimum yield and water use efficiency were 1150.0 kg ha^{-1} and 0.17 kg m^{-3}, respectively for 60% potential evapotranspiration and within row spacing of 15 cm.

INTRODUCTION

Beans are considered as one of the most important food resources and are necessary for human and animals because of being rich in proteins. Beans contain 18-23 percent of protein. They are cost-effective for people with low-income and those who cannot afford sources of animal protein.

Drought and nutritional deficits in the soil are the most common non-biological stresses that affect the production of bean (Majnoon Hosseini, 2008). In a study, Emam et al. (2010) investigated the effect of water stress on two cultivars of red bean (Sayad and D81083) in the research farm at Shiraz University. Their results showed that the height of plant, number of leaves, leaf area index and the number of pods and their dry weights were highly affected by water stress. Torabi Jofroodi et al. (2007) reported that different row spacing can affect yield and some yield components of red bean. Their various settings of row spacing were 30 cm, 45 cm and 60 cm. They achieved the highest yield when the row spacing was 30cm, making a yield of 4191 kg/ha. Many factors influence the increase of yield including the climate, soil, type of species, preparation of proper bedding, date of sowing the seeds, method of appropriate planting, the amount of seeding and crop rotation. Nowadays, beans are a major source of protein, calorie, fiber and minerals for populations in developed countries (Ramos et al., 1999; Simsek et al., 2011).

The production of plant dry matter is a function of absorbed light by the leaves during the process of growing. The efficiency of light absorbance by the plant is affected by canopy structure. A precondition that is required for the acquisition of high yield is to provide a proper condition for the optimization of radiation to enable photosynthesis at the highest efficacy. The biomass is produced thereupon and is directly associated with the rate of absorbed light by the canopy (Muchow, 1990). The Leaf Area Index (LAI) profile is a measure to estimate the amount of radiation received by a plant which can highly affect the biological yield of the plant. The importance of leaf area index in a plant community is actually due to the nature of photosynthesis being considered as a process of organic matter production in the leaf (Geng et al., 2000). An accurate measurement of leaf area index can give a better understanding of the mutual effects between plant growth and the environment (De Jesus et al., 2001). On the contrary, the use of direct methods is time-consuming and needs more manpower. Therefore, they cannot be a proper method for monitoring the changes in leaf area index during growth (Chason et al., 1991). Indirect methods estimate leaf area index by using other variables, through high speed and capability. They enable sampling in vast areas and thus are more appropriate than direct methods due to the ease of their enactment. Macfarlane et al. (2007) evaluated leaf area index of broad-leaved plants by a non-destructive method. Accordingly, three digital photographs, fisheye circles and fisheye frames were used. In order to extract data Photoshop, Wins canopy, DHP-TRACW and Hemi view software were used. Tests were done in a 17-year Eucaly ptus forest by the density of 625, 1250, 2500 and 10000 trees in a hectare. They stated that the digital photographs for indirect evaluation were more precise than the other two methods. David et al. (2012) reported that the data set previously collected would be useful for calibrating and validating Aqua Crop. These contain only leaf area index (LAI) data but could be used if relationships were available, thereby establishing a correlation between LAI and canopy cover (CC). The objective of their experiment was to determine relationships between LAI and CC for corn (*Zea mays* L.), winter wheat (*TriticumaestivumL.*) and spring triticale (*Triticosecale* spp.) grown under rain-fed irrigation or supplementary irrigation of very limited amounts. The LAI and CC data were collected during 2010 and 2011 at Akron, CO, and Sidney, NE, by using a plant canopy analyzer and a point analysis of above-canopy digital photographs. Strong relationships were found between LAI and CC that followed the exponential rise to a maximum form. The relationship for corn was similar to a previously published relationship for LAI <2 $m^2\ m^{-2}$ but it predicted a lower CC for greater LAI. Relationships for wheat and triticale were similar to each other. Carlos et al. (2015) reported that leaf area index (LAI) is one of the key biophysical variables required for crop modeling. Direct LAI measurements are time-consuming and difficult to obtain for experimental and commercial fruit orchards. The devices that are used for estimating the LAI have shown considerable errors when compared to ground-truth or destructive measurements, requiring tedious site-specific calibrations. The objective of that study was to test the performance of a modified digital cover photography method to estimate LAI in apple trees by using conventional digital photography and the instantaneous measurements of incident radiation (Io) and transmitted radiation (I) through the canopy. Leaf areas of 40 single apple trees were measured to obtain real leaf area index (LAID). This was then compared with the LAI, estimated by the proposed digital photography method (LAIM). Results showed that the LAIM was able to generate an approximate value for LAID by using a constant light extinction coefficient (k = 0.68), while potentially bearing a 25% error. Water stress and different levels of cultivation densities of plants can affect the seed yield and other effective factors such as the leaf area index and canopy cover of each plant. In line with the aforesaid argumentations, the current` research studies the effects of water stress and different levels of cultivation densities of red bean (Akhtar cultivar) on the yield of beans.

MATERIALS AND METHODS

The research field was located in the College of Agriculture at Shiraz University during the years 2013 and 2014. This locality is approximately 1810 meters above the sea level, and is situated in a geographic coordination of 29° 56 ’ N, 52° 02 ’E. The predominant soil is characterized as being silty clay loam (Table 1). Tests on the chemistry of soil indicated that the amount of fertilizer required for cultivating agronomic crops in the research field is 250 Kg/ha urea fertilizer and 250 Kg/ha superphosphate fertilizer. Chemical analysis of the irrigation water is shown in Table 2.

Table 1. Physico-chemical properties of the soil at the experimental site.

Characteristic	Soil depth(cm)		
	0-15	15-30	30-60
Field capacity (%)	0.302	0.322	0.336
Permanent wilting point (%)	0.196	0.198	0.208
%Sand	11	10	16
%Silt	56	51	50
%Clay	33	39	34
Texture	SCL	SCL	SCL
EC(ds m^{-1})	0.74	0.51	0.49
C^{l-}(meq l $^{-1}$)	5.31	3.05	2.9
Na^+(meq l $^{-1}$)	3.29	1.97	1.91
Ca^{2+}(meq l $^{-1}$)	5.43	4.16	4.07
Mg^{2+}(meq l $^{-1}$)	3.5	2.88	2.84

Table 2. Chemical analysis of irrigation water used in the experiment (average of two years)

Characteristic	Amount
EC(ds m-1)	0.45
pH	7.58
Cl^-(meq l $^{-1}$)	0.8
Na^+(meq l $^{-1}$)	0.7
Ca^{2+}(meq l $^{-1}$)	4
Mg^{2+}(meq l $^{-1}$)	3
HCO_3^-(meq l $^{-1}$)	4
SO_4^{2-}(meq l $^{-1}$)	2.5

The initial irrigation schedule here was to irrigate the land until the bean plants reached their four-leaf stage; thereafter, irrigation continued every other week according to the four irrigation treatments: 1.2, 1, 0.8 and 0.6 times of potential evapotranspiration of red bean and because of presence of deep groundwater table, it had a free drainage condition; each experimental unit measured 6 meters long and 3 meters wide (Fig. 1).The experiment was divided into split-plots in four levels of irrigation and three conditions of spacing. There were three replications. The first factor considered in the experiment was four levels of irrigation.

I4D2R3	I1D1R1	I4D2R2
I4D1R3	I1D2R1	I4D1R2
I4D3R3	I1D3R1	I4D3R2
I1D2R3	I2D2R1	I1D3R2
I1D1R3	I2D1R1	I1D2R2
I1D3R3	I2D3R1	I1D1R2
I2D2R3	I3D3R1	I2D2R2
I2D1R3	I3D2R1	I2D1R2
I2D3R3	I3D1R1	I2D3R2
I3D3R3	I4D2R1	I3D2R2
I3D2R3	I4D1R1	I3D3R2
I3D1R3	I4D3R1	I3D3R2

Fig. 1. Layout of experimental field at different irrigation strategies and plant density.

These were regulated deficit irrigation (I1), deficit irrigation (I3), full irrigation (I2) and excessive irrigation (I1), each displaying 60, 80, 100 and 120% of potential evapotranspiration, respectively. The second factor was within row spacing which was set to be of three distances within the rows, i.e., 5 cm (D1), 10 cm (D2) and 15 cm (D3) and 30 cm row spacing at three replication R1, R2 and R3. Soil water content at 0.2, 0.4 and 0.6 m depths was measured with weighted method before each irrigation event. During periods, irrigation water was applied in a 7-day interval. Evaporation from the soil surface was measured by using microlysimeter. The weight of dry matter and leaf area index were measured in each treatment, by intervals of two weeks, whereby the margin effect was also taken into account in each experimental unit. One plant was harvested from each unit as a representative and the aforesaid parameters were measured. Canopy cover of the plant was measured using image processing in Mat lab software, based on photos provided vertically and digital photos from the red bean farm land. The photos were taken from a distance of 1.5 meters from the ground. The MSTAT-C software was used for the analysis of data variance.

Reference evapotranspiration (ETo) was calculated using modified Penman–FAO equation for semi-arid environments in the study area (Razzaghi and Sepaskhah, 2012). The potential crop evapotranspiration for the time intervals between measurements of soil water content was estimated by the water balance procedure as follows:

$$ET_a=I+P-D_p\pm \Delta S \quad (1)$$

Where I is the irrigation depth (mm), P is the precipitation (mm), D_p is the deep percolation (mm) from the bottom of root zone and ΔS is the variation of soil moisture in root depth (mm).

Water use efficiency (WUE, kg/m^3) is a quantitative term used to define the relationship between crop produced and actual evapotranspiration. It can be calculated as follows: (Hussain et al., 1995):

WUE= Grain yield (kg/ha)/ Actual evapotranspiration (m^3/ha).

RESULTS AND DISCUSSION

When the soil is wet, the soil water has potential energy and is easily taken up by plant roots. In dry soils, water has a low potential to be taken up by crop roots. The experimental field was bare before planting and because of presence of deep groundwater table; it had a free drainage condition. Therefore, the field was well-drained and the penetrated winter rainfall was stored in the soil against gravitational drainage. The top layer of soil was exposed to direct radiation and became dry before planting. Soil water content increased by irrigation. As time progressed, because of deep percolation, plant uptake and evaporation, soil water content decreased. The amount of soil water contents is shown in Fig (2) before planting in 2013 and 2014, respectively. The distribution of soil water contents with depth before irrigation, in 94 and 71 days after planting in different irrigation treatments in 2013 and 2014, respectively is shown in Fig (3).

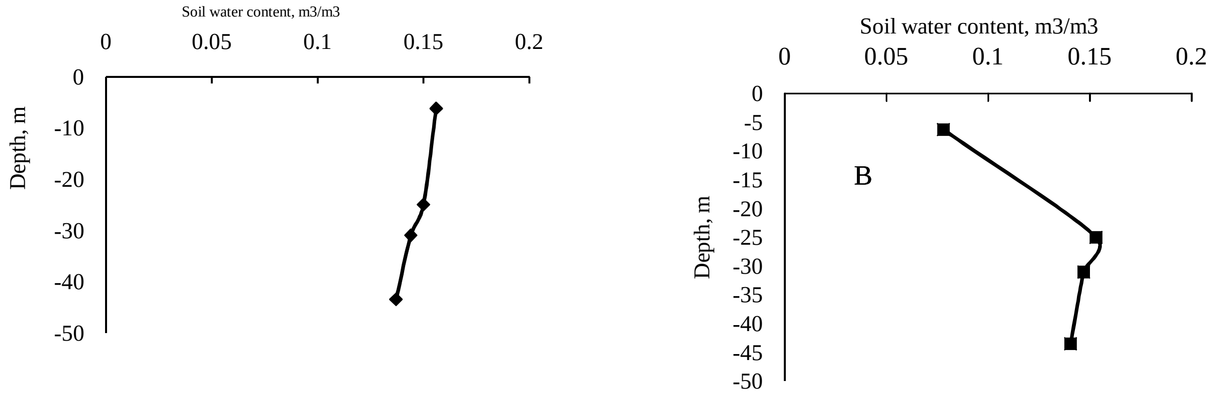

Fig. 2. Volumetric soil water content before planting, in 2013 (A) and in 2014 (B).

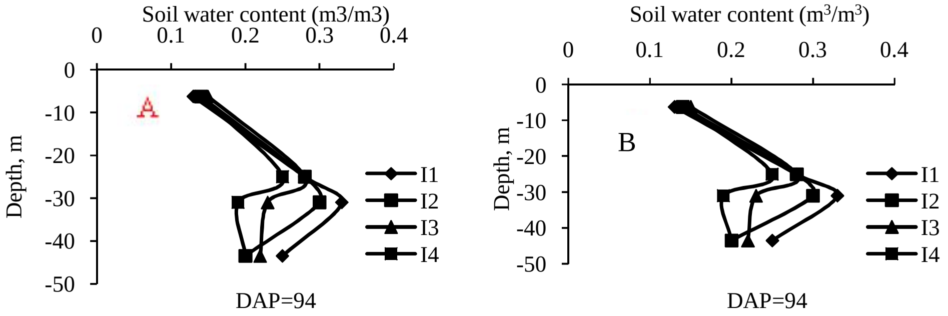

Fig. 3. Volumetric soil water content in 94 and 71 days after planting, in 2013 (A) and in 2014 (B), respectivelyEvapotranspiration

Figures 4 and 5 illustrate seasonal actual evapotranspiration in different treatments during 2013 and 2014 in growing seasons, respectively. Actual evapotranspiration (Eta) ranged from 580-735 mm and 550-700 mm, respectively, during 2013 and 2014 in growing seasons. The maximum Eta observed in treatments I1 and I2 was 735 mm in 2013. The minimum Eta observed in treatment I4 was 580 mm in 2013. The maximum Eta observed in treatments I1 and I2 was 700 mm in 2014. The minimum Eta observed in treatment I4 was 550 mm in 2014.

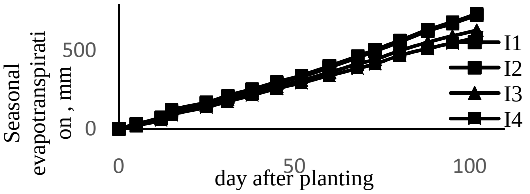

Fig. 4. Seasonal evapotranspiration in different irrigation treatments, in 2013

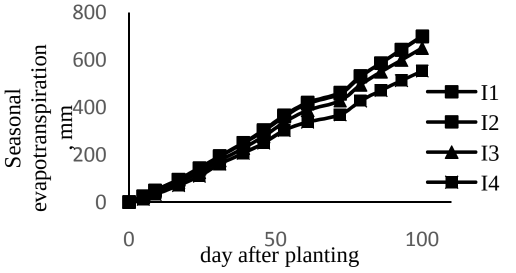

Fig. 5. Seasonal evapotranspiration in different irrigation treatments, in 2014

Total Changes in Dry Matter (biomass)

The accumulation trend for plant dry matter (biomass) showed that the maximum dry matter was achieved when there was 100% potential evapotranspiration irrigation. The minimum dry matter, however, occured at 60% potential evapotranspiration irrigation (Fig. 6). The accumulation trend for dry matter can be divided into two steps. The first step is at the time when plants receive 730 Growing Degree Days (GDD). The second step involves an extraordinary accumulation of dry matter which reaches a maximum trend corresponding to about 1700 GDD. Thereafter, the rate of dry matter accumulation declines as the plant moves toward the end of the growing period.

It was found that the rate of dry weight accumulation increases as a result of an increase in irrigation. Reasons for the slow trend of increase in biomass at the beginning of the growing period are explained by the small size of leaf area because the seedling is too small to perform effective exploitations of environmental resources, especially light. Consequently, it is presumed that water stress reduces the leaf area; thus, the plant becomes less able to receive light. Therefore, photosynthesis is suppressed and the yield is affected, even though the density of plant cultivation is higher in comparison with normal irrigation conditions.

The accumulation trend of the total biomass in different densities of plant cultivation shows that the weight of dry matter can be highest when there is a density of 66 plants per square meter and the least dry matter is obtained at a density of 22 plants per square meter (Fig.7). The build-up of biomass can be divided into three trends, regardless of the cultivation density. The first trend is a slow build-up of organic matter in the plant which occurs at 730 GDD. The second trend is a faster accumulation because of the increasing rate of growth occurring at 1700 GDD. The last trend under goes a slow-down of biomass build-up which continues until the end of the growing period.

It is shown that the dry weight increased by an increase in irrigation. Reasons for the slow build-up of biomass in the first phase of the trend were explained earlier. Reasons for the second trend of rapid increase in dry matter can be explained by the increase in leaf area leading to a more efficient absorption of sunlight by plants. A higher density of cultivation provides for more sufficient leaf area when considering the population of cultivated plants as a whole. As the absorption of sunlight is optimized, the efficiency of energy consumption by plants is also improved which results in the increase of yield. Reports of TorabiJafroudi et al. (2007) and Sirait et al. (1994) are in line with these claims.

Leaf Area Index (LAI)

Results of this experiment show that the trends of leaf area growth are similar to the trends of biomass build-up described earlier. In the beginning of the growing period, bean leaf area expands slowly, but is then followed by a linear trend of increase that reaches a maximum when corresponding to about 1350 GDD. Thereafter, the trend slows down because of senescence as the plant prepares to shed its leaves (Fig. 8, 9). Leaf area is directly related to the rate of irrigation in a manner that the maximum leaf area of a single leaf is related to the irrigation corresponding to the rate of potential evapotranspiration. Its minimum rate, however, occurs when having 60 percent of the potential evapotranspiration (Fig.8). Furthermore, the leaf area has a direct relation with the density of cultivation. Maximum leaf area of a single leaf occurs when there is a density of 66 plants per square meter. The minimum amount of leaf area occurs at the density of 22 plants per square meter (Fig. 9). These results are in agreement with those by Singh et al. (1998) and Fateh et al. (2006) and Ghassemi-Golezani et al. (2014).

Canopy Cover (CC)

Results show that the CC of bean plants increases slowly at the initial stage of growth, but then it increases at a faster rate by a linear trend and reaches a maximum canopy cover when at about 1350 GDD. Thereafter, the rate of canopy growth declines due to senescence as the plant physiology organizes to shed leaves (Fig.10, 11). The CC is directly related to the rate of irrigation water in a way that the maximum leaf area of a single leaf is related to the irrigation which corresponds to the rate of potential evapotranspiration. Its minimum rate is related to a treatment of 60 percent of potential evapotranspiration (Fig. 10). Furthermore, the CC is affected by the density of cultivation too. The maximum CC occurs when there is a density of 66 plants per square meter and its minimum happens at a density of 22 plants per square meter (Fig. 11). These results confirm earlier reports by Fateh et al. (2006) and Ghassemi-Golezani et al. (2014).

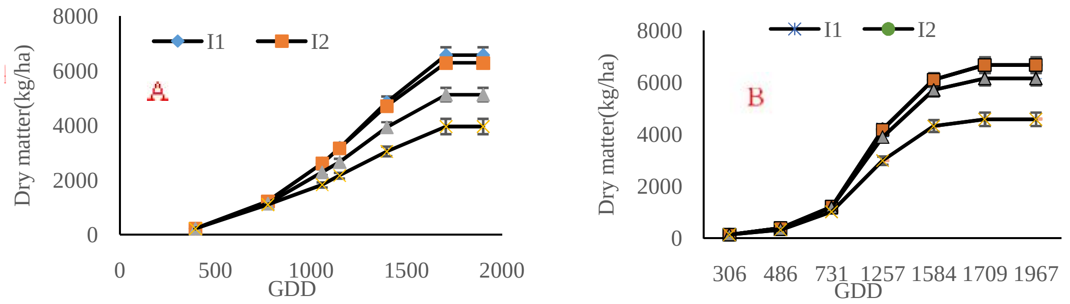

Fig. 6. Trend changes of dry matter in different treatments of irrigation in 2013 (A) and in 2014 (B) Irrigations: Irrigation I1 corresponds to 1.2 of the potential evapotranspiration, irrigation I2 corresponds to 1.0 of the potential evapotranspiration, Irrigation I3 corresponds to 0.8 of potential evapotranspiration, Irrigation I4 corresponds to 0.6 of the potential evapotranspiration

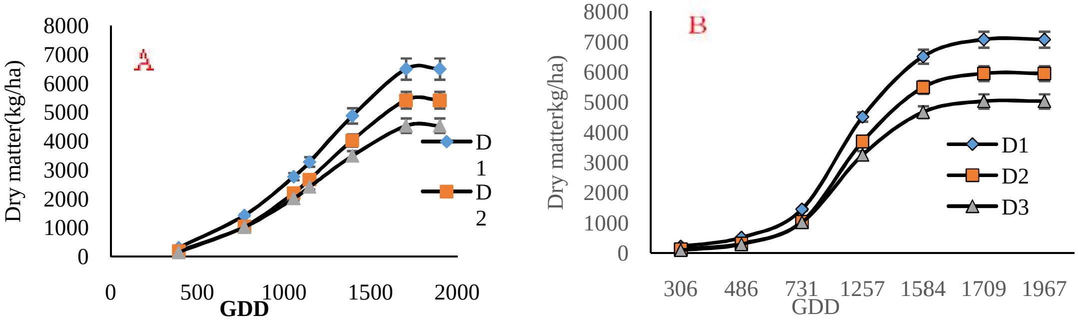

Fig. 7. Trend changes of dry matter in different densities of cultivation in 2013 (A) and in 2014 (B) Density: Density D1 shows density of 66 plants and D2 shows density of 33 plants and D3 shows density of 22 plants per square meter.

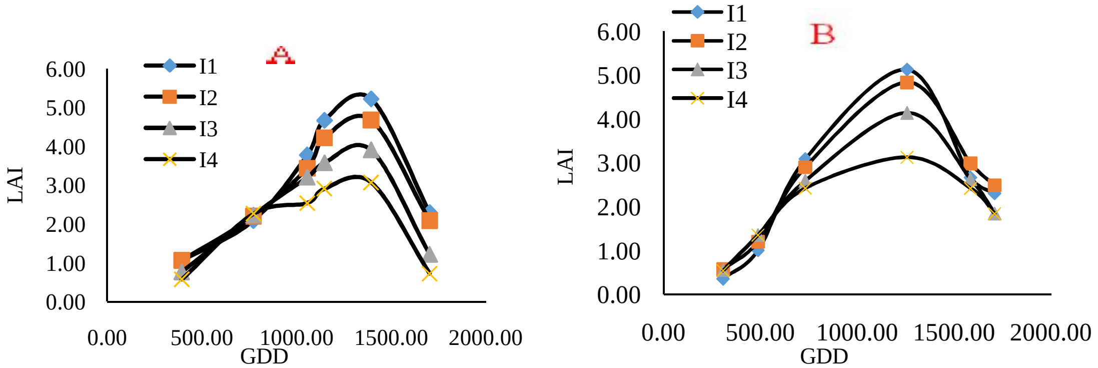

Fig. 8. Trend changes of Leaf area index in different treatments of irrigation in 2013 (A) and in 2014 (B) Irrigations: Irrigations I1, I2, I3 and I4 correspond to 1.2, 1.0, 0.8 and 0.6 of the potential evapotranspiration, respectively

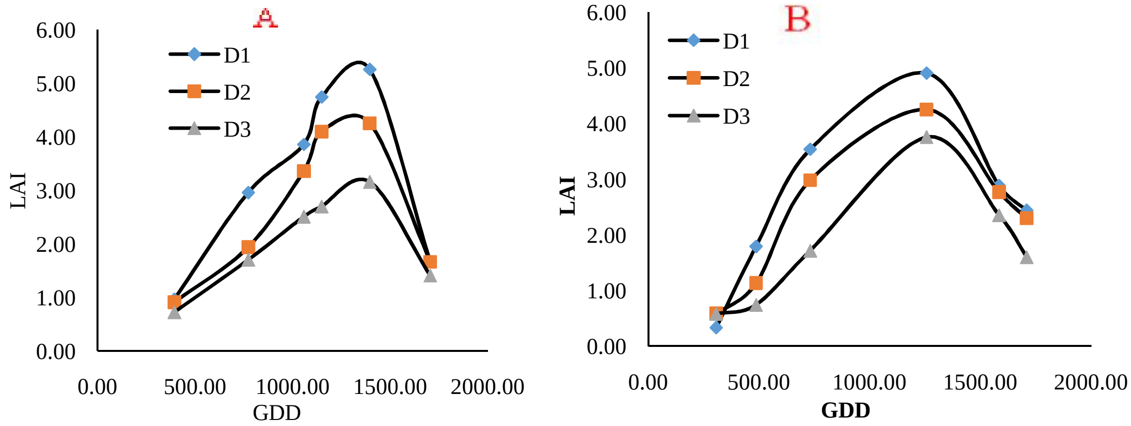

Fig. 9. Trend changes of Leaf area index in different densities in 2013 (A) and in 2014 (B) Density: Density D1 shows density of 66 plants and D2 shows density of 33 plants and D3 shows density of 22 plants per square meter.

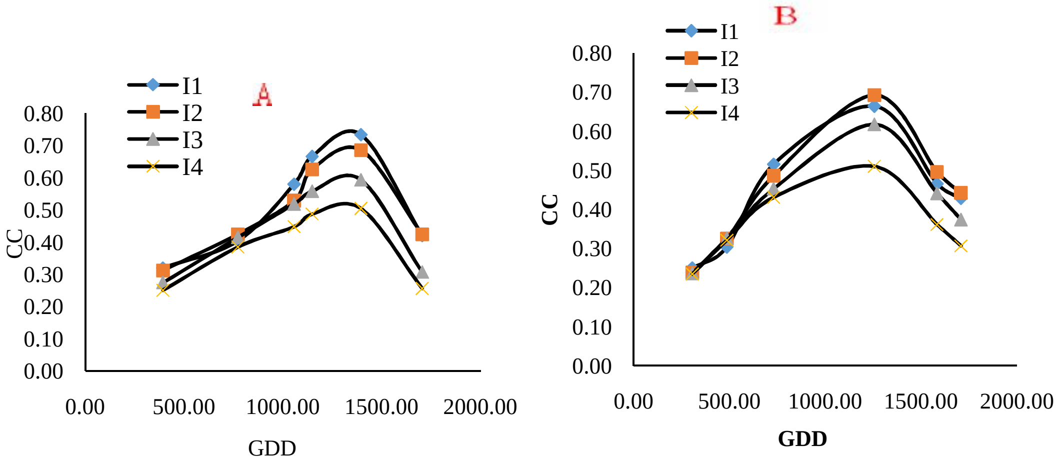

Fig. 10. Trend changes of canopy cover in different treatments of irrigation in 2013 (A) and in 2014 (B) Irrigations: Irrigations I1, I2, I3 and I4 correspond to 1.2, 1.0, 0.8 and 0.6 of the potential evapotranspiration, respectively.

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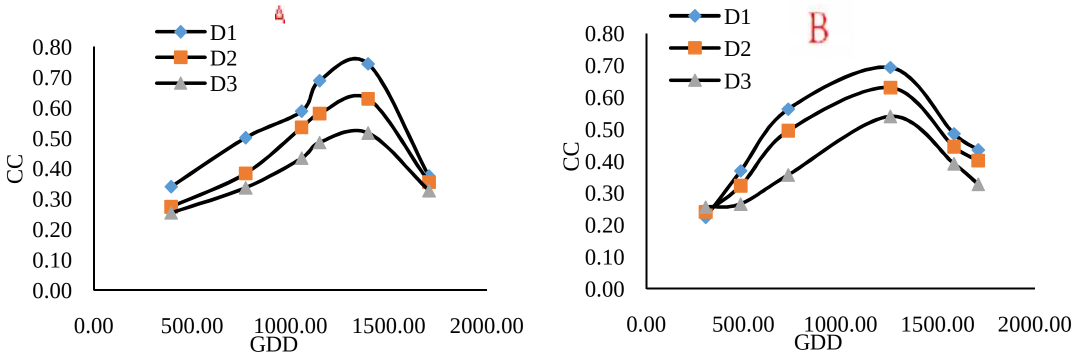

Fig. 11. Trend changes of canopy cover in different densities in 2013 (A) and in 2014 (B) Density: Density D1 shows density of 66 plants and D2 shows density of 33 plants and D3 shows density of 22 plants per square meter.

Relationship between LAI and CC

To study the correlation between leaf area index and CC in the years 2013-2014, all treatments were reviewed without considering the density of cultivation and the amount of irrigation water. Accordingly, the following equation was obtained from the regression between LAI and CC for all samples during the growing season. Equation 3 is related to the year 2013 and Equation 4 is related to the year 2014.

$$CC=0.24 * e^{0.22LAI} \; R- 0.91 \quad (3)$$

$$CC=0.23 * e^{0.23LAI} \quad R- 0.90 \qquad (4)$$

Yield of Seed

The analysis of variance showed that the effects of irrigation, row spacing and their interaction all significantly influenced the net dry matter and final yield of bean in 2013 and 2014 ($p<0.05$) (Table 3). In both years, the maximum yield pertained to the cultivation density of 66 plants per square meter and the irrigation corresponding to the rate of potential evapotranspiration. The yield averaged 3061.8 kg/ha in 2013 and increased to 3305.2 kg/ha in 2014. On the other hand, the minimum yield was achieved through the cultivation density of 22 plants per square meter while having the irrigation treatment at 0.6 of potential evapotranspiration (Fig. 7). Accordingly, the yield averaged 834.2 kg/ha in 2013 and 1150.0 kg/ha in 2014 (Table 5). Indeed, by increasing the plant density, it was observed that the grain yield increased. The reason lies in the fact that when plants are cultivated at higher densities, the sub branches are more likely to grow at the lower part of the plant which can be more productive (Gharib Ardakani and Farajee, 2013). The stress treatments caused the yield of bean to decrease by premature flower loss and the decline in young pod numbers in plants, all of which affected the weight of seeds. Dry stress, indeed, can significantly reduce the yield of bean (Razzaghi et al., 1997; Rezaie et al., 2014). These results lead us to the conclusion that dry stress reduces the plant ability to use light, thereby hampering photosynthesis and reducing the seed yield, even when there is a higher density of cultivation and also when these experimental conditions are compared with normal irrigation conditions. It has previously been reported that the grain yield of beans significantly decreases under water stress conditions (Emam et al., 2010). Similar reductions in the yield have frequently been reported, i.e. by Karam et al. (2005) in soybean, Cakir (2004) and Payero et al. (2006) in corn and Karam et al. (2007) in sunflower. Application of adequate water during flowering and pod development is the most significant factor in bean irrigation.

Table 3. Analysis of variance for bean yield and Dry matter (2013 and or 2014)

Source of variation	Degree of freedom	Dry matter 2013	Dry matter 2014	Yield 2013	Yield 2014
Replication	2	2187.000^{ns}	4624.75^{ns}	254.47^{ns}	10.783^{ns}
Density	2	9144601.000**	12311419.75**	1832515.721**	1846829.286**
Irrigation	3	11233907.667**	10692596.296**	3840227.086**	3109500.33**
Irrigation*Density	6	337207.667**	168623.046**	83274.357**	92910.451**
Error	18	7920.333	4954.880	955.554	2727.099

*Significant at P < 0.05; **significant at P < 0.01; ns, not significant

Table 4. Comparison of seed yield average and dry matter of bean affected by plant density and Irrigation(2013 and 2014)

Within row spacing (cm)	Dry matter 2013 (kg/ha)	Dry matter 2014 (kg/ha)	Yield 2013 (kg/ha)	Yield 2014 (kg/ha)
5	6335a	7061a	2393a	2682a
10	8495b	5970b	1991b	2234b
15	4590c	5037c	1611c	1900c
Irrigation				
1.2ET	6440a	6807a	2589a	2735a
1.0ET	6137b	6757a	2424b	2686a
0.8ET	5379c	6056b	1833c	2197b
0.6ET	3937d	4471c	1148d	1469c

Each column in each treatment shows the difference between two mean values. Common letters denote insignificant differences between mean values by the Duncan test (*$P < 0.5$*)

Table 5. Comparison of average of mutual effects of plant density and species on the yield and dry matter of bean (2013 and 2014)

Irrigation regim	Within row spacing (cm)	Dry matter 2013 Kg/ha	Yield 2013 Kg/ha	Dry matter 2014 Kg/ha	Yield 2014 Kg/ha
1.2ETs	5	7290.1a	3061.8a	7870.3a	3305.2a
1.2ETs	10	6630.4a	2652.0b	6591.2a	2636.1b
1.2ETs	15	5400.0c	2052.1e	5960.1b	2265.1d
1.0ETs	5	7320.2e	3001.2g	7935.1f	3254.4a
1.0ETs	10	5770.1b	2250.3c	6720.0c	2620.0b
1.0ETs	15	5319.7c	2021.3d	5750.1b	2185.3d
0.8ETs	5	5780.3c	2023.3f	6748.2d	2361.2c
0.8ETs	10	5700.2g	1938.1h	6150.4h	2230.2d
0.8ETs	15	4657.7d	1537.0e	5269.0fe	2000.7e
0.6ETs	5	4950.3d	1485.2e	5690.1ff	1807.0f
0.6ETs	10	3880.0f	1125.4g	4420.2g	1450.3g
0.6ETs	15	2980.2h	834.2i	3301.8i	1150.0h

Within rows or columns means within the same letter are not significantly difference ($P < 0.05$)

Accordingly, similarities were observed in this study for the common bean that was cultivated in the semi-arid zone. Similar trends in the yield were seen for the yield components in all irrigation treatments of this study. Water stress combined with high temperature during flowering of the bean brought about a decrease in all yield components.

CONCLUSIONS

Considering the results of this research, we can conclude that bean, in general, is substantially susceptible to drought stress. The decrease in yield caused by drought stress can be explained by the loss of flowers and also the decrease in the number of bean pods per plant. These consequently affect the number of seeds in each pod. Results showed that by increasing the density of cultivation, there will still be enough leaf area for sunlight to be received. This, in fact, optimizes energy consumption by the plant and ultimately increases the yield and its components. In 2013, the maximum yield occurred when the irrigation was by 1.2 times the potential evapotranspiration and the maximum efficiency of water use occurred when the irrigation was by 1.0 times the potential evapotranspiration; in 2014, however, the potential evapotranspiration sufficed to yield the maximums. Both years reached their maximum yields under the cultivation density of 66 plants per square meter. The minimum rate of water use efficiency occurred when irrigation was set by 0.6 of the potential evapotranspiration, with a plant density of 22 plants per square meter. Generally, results indicate that the maximum yield and other properties relating to the yield are developed when the plant cultivation density is 66 plants per square meters. Water stress, similarly, has significant impacts on the yield and other relevant properties of the red bean, whereby the quality and quantity of yield decrease. These ultimately culminate in the reduction of water use efficiency. Therefore, maximum yield is acquired via ample irrigation as described previously, and also by within the row spacing of 5 cm, which cause the yield to increase nearby by four-fold.

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اثر تراکم کاشت و چهار استراتژی آبیاری بر عملکرد و پوشش سبز گیاه لوبیا قرمز، رقم اختر

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واژه های کلیدی:

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فاصله کاشت
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چکیده-به منظور بررسی اجزای عملکرد لوبیا قرمز رقم اختر، آزمایش هایی در سال ۱۳۹۲ و ۱۳۹۳ در مزرعه تحقیقاتی دانشکده کشاورزی دانشگاه شیراز در قالب کرت‌های خرد شده در چهار سطح آبیاری و سه سطح فاصله کاشت در سه تکرار اجرا شد. در این تحقیق فاکتور اول مورد بررسی چهار سطح آبیاری در سطوح I1 ، I2 ، I3 و I4 (۱۲۰، ۱۰۰، ۸۰ ، ۶۰ درصد تبخیر- تعرق واقعی) و فاکتور دوم فاصله کاشت روی ردیف به میزان ۵، ۱۰ و ۱۵ سانتی متربود. نتایج این تحقیق نشان می‌دهد که ماده خشک و عملکرد دانه در فواصل مختلف کاشت و آبیاری دارای اختلاف معنی‌دار می‌باشند. نتایج نشان می‌دهد که ماده خشک و عملکرد دانه با افزایش تراکم و آبیاری افزایش می‌یابد. در این تحقیق بیشترین عملکرد در سال ۱۳۹۲ مربوط به آبیاری ۱۲۰ درصد میزان تبخیر تعرق واقعی با فاصله کاشت ۵ سانتی‌متر، به مقدار ۳۰۶۱/۸ کیلوگرم بر هکتار و وبیشترین میزان راندمان مصرف آب مربوط به آبیاری ۱۰۰ درصد میزان تبخیر تعرق واقعی با فاصله کاشت ۵ سانتی‌متر، ۰/۳۳ کیلوگرم بر متر مربع و کمترین عملکرد مربوط به آبیاری ۶۰ درصد میزان تبخیر تعرق واقعی و راندمان مصرف آب با فاصله کاشت ۱۵ سانتی‌متر، به ترتیب برابر با ۸۳۴/۲ کیلوگرم بر هکتار و ۰/۱۲ کیلوگرم بر متر مربع حاصل گردید و در سال ۱۳۹۳ بیشترین عملکرد و راندمان مصرف آب مربوط به آبیاری ۱۰۰ درصد میزان تبخیر تعرق واقعی با فاصله کاشت ۵ سانتی‌متر، به ترتیب به مقدار ۳۳۰۵/۲ کیلوگرم بر هکتار و ۰/۳۴ کیلوگرم بر متر مربع و کمترین عملکرد و کارایی راندمان مصرف آب مربوط به آبیاری ۶۰ درصد میزان تبخیر تعرق واقعی با فاصله کاشت ۱۵ سانتی‌متر، به ترتیب برابر با ۱۱۵۰/۰ کیلوگرم بر هکتار و ۰/۱۷ کیلوگرم بر متر مربع حاصل گردید.