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Study of Deficit Irrigation in Different Common Bean (*Phaseolus vulgaris* L.) Cultivars at Shahrekord Region

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ABSTRACT

Common bean is an important crop in Chaharmahal and Bakhtiari province with high water requirement and in recent years, due to water scarcity, its cultivation has declined sharply. In this experiment, deficit irrigation with change irrigation method in bean cultivars were investigated. Factorial experiment was conducted in a randomized complete block design with three replications in 2016 and 2017 at Chahartakhte Research Station in Shahrekord region. Cultivar with three levels (Koosha chitti bean, Yaghut red bean and Dorsa white bean) and irrigation method with three levels (strip-drip irrigation, furrow irrigation, and conventional (flood) irrigation (strip surface irrigation)) were used in this experiment. Combined analysis results showed that plant height, grain yield, yield components, and water productivity were affected by bean cultivars and irrigation methods. The highest grain yield was obtained from Yaghut red bean cultivar, which had a significant difference with Koosha chitti bean cultivar. The highest water productivity was obtained from Yaghut red bean cultivar, which had a significant difference with other common bean cultivars. The highest water productivity was obtained from strip surface irrigation, which did not have a significant difference with strip drip irrigation, while water use in strip drip irrigation was far less than strip surface irrigation. Therefore, it is possible to use drip irrigation with less water consumption.

Keywords: Common bean, Yield, Reduce irrigation, Water productivity.

INTRODUCTION

One of the main elements of sustainable development in any country is to provide sufficient food at a reasonable price for its people. Nowadays, due to resources constraint and increasing population growth, it is necessary to use optimally of limited resources (Kamali et al., 2008). Human awareness of the importance and essential role of protein has provided a special role for this dietary composition. Due to limitations of animal protein production, the focus of researchers is on meeting protein needs through plant products. Studies have shown that a good combination of plant protein can eliminate malnutrition and protein deficiency (Salehi, 2010).

Legumes are among the plants that are high in protein and have an important role in providing human protein materials with 18 to 32% protein. However, low levels of amino acid lysine can also be offset by using legumes. Coexistence with nitrogen-fixing bacteria in their roots also plays an important role in soil fertility, and after their harvest, large amounts of nitrogen are added to the soil. Therefore, legumes play an important role in crop rotations; moreover, since the past time, their cultivation with cereals or in rotation with them has been conventional. These plants are also used as green manures to enhance and improve the physical condition of the soil. Legumes are the second most human abundant source of plant protein after cereals (Broughton et al., 2003; Fageria and Santos, 2008; Salehi, 2010).

Comprehensive and regular information on common bean (*Phaseolus vulgaris* L.) is not available in strip-drip irrigation application. Although observational work in places such as Khomein (personal observations) and Zanjan have proved usefulness of its irrigation method, but they have not been documented. Strip-drip irrigation has been studied on various crops such as sugar beet (*Beta vulgaris*), maize (*Zea mays*), soybean (*Glycine max*), cotton (*Gosipium hirsutum*) and rapeseed (*Brassica napus*). Salemi et al. (2014) showed in sugar beet that water use efficiency in sugar yield was obtainable in strip-drip irrigation of 65 and in furrow irrigation of 53 kg m^{-3}. Mohammadian and Sadreghaein (2012) proposed planting arrangement of 40-60 cm (row spacing) and placing an irrigation strip for two rows of sugar beet. Akhavan et al. (2014) obtained the highest corn grain yield at 75000 plant density and one row planting arrangement. The highest water use efficiency (1.65 kg m^{-3}) was obtained from this planting arrangement with strip-drip irrigation. Karimi and Yousef-gomrokchi (2007) obtained the highest corn grain yield in strip-drip irrigation with a water use efficiency of 3.75 kg m^{-3}. Shahinrokhsar and Asadi (2012) showed in soybean that strip-drip irrigation reduced water consumption by 63%. The efficiency of water use in soybean drip irrigation was 1.09 kg m^{-3}, which was significantly different from the furrow irrigation method (0.5 kg m^{-3}).

Climate change as global warming has caused anomalous climatic phenomena, often in the form of water shortages or floods. In both cases, severe drought develops due to prolonged exposure to water deficit conditions. Drought, as an abiotic stress, is multidimensional in nature, affecting plants at different structural levels (Salehi, 2015b). Therefore, the existence of water deficit is unavoidable. Common bean is a crop that grown in Chaharmahal and Bakhtiari province with high water consumption and in recent years due to water scarcity problems, the area under its cultivation has severely decreased. The area under cultivation of beans in Chaharmahal and Bakhtiari province has dropped from about 11,000 to less than

4,000 hectares, largely due to water scarcity in recent years. While common bean requires to 7,000 to 8,000 m^3 of water during the growing season (Alizadeh, 2003), farmers consume more than 15,000 m^3 of water per hectare during the growing season. Using strip-drip irrigation can reduce common bean water consumption to less than 8,000 m^3 during the growing season. Using this irrigation method requires changing the planting method, using the furrow planting, and irrigating by using strip-drip irrigation. Therefore, the aim of this experiment was to investigate the reduction of water use in common bean and to determine the amount of water use in different irrigation methods in common bean cultivars. Other goals of this project are to help reduce water use and increase water use efficiency, which can help the sustainability of common bean cultivation in the long term as regards the drought in the country.

MATERIALS AND METHODS

Deficit irrigation was investigated with using different irrigation methods in common bean cultivars. The experiment was carried out as a factorial experiment in a randomized complete block design with three replications in spring and summer of 2016 and 2017 at Chahatakhteh research station in Shahrekord region. Cultivar with three levels (Koosha chitti bean, Yaghut red bean and Dorsa white bean), and irrigation method with three levels (strip-drip irrigation (I_1), furrow irrigation (I_2), and conventional (flood) irrigation (I_3) (strip surface irrigation)) were used in this experiment. Planting was done manually and plant density was constant about 40 plants m^2. During the experiment, vegetative and reproductive stages of common bean were recorded and yield and yield components were determined at the end of the growing season. Water consumption was measured by contour in each method. Each experimental plot consisted of one of the cultivars with a irrigation method.

The experimental farm was selected at the beginning of spring 2016 and 2017 and twice perpendicular to plowing. Then, according to the soil test, the required amount of fertilizer was given to the soil and mixed with it by disk. Subsequently, according to the project map, the plots and irrigation systems were implemented. In 2016, the seeds of each cultivar were planted on June 2nd and in 2017 on May 29th. During the vegetative period, necessary agricultural care such as irrigation, weeds, pest and disease control were provided. After the common bean cultivars were matured, the crop was harvested and the yield of the plots was weighed. Samples were taken from each plot and transferred to the laboratory for determination of seed yield components (number of pods per plant, number of seeds per pod and 100-seed weight). Data were analyzed using SAS statistical software and the means were compared using Tukey's test.

RESULTS AND DISCUSSION

Results of deficit irrigation with irrigation method in different common bean (*Phaseolus vulgaris* L.) cultivars at Shahrekord region on bean characteristics have been reviewed in Tables 1 to 4.

Table 1) Data combine analysis of plant height, number of pods per plant, number of seed per pod, 100-seed weight, grain yield and water productivity in irrigation methods and bean cultivars in two years.

Source of variation	Degree of freedom	Means of Squares					
		Plant height	Number of pods per plant	Number of seed per pod	100-seed weight	Grain yield	Water productivity
Year (Y)	1	0.015 ns	1130.25**	2.647**	89.96**	277726.5**	0.0036**
Replication per year	4	22.246	16.75	0.0512	2.869	2773.5	0.000024
Cultivar (C)	2	299.71**	248.91**	0.736**	1318.70**	2117683.5**	0.0147**
Y*C	2	57.89 ns	50.03**	0.024 ns	13.71**	784977.8**	0.0062**
Irrigation method (I)	2	144.34**	75.70**	1.274**	61.81**	14014923.1**	0.0119**
Y*I	2	53.33 ns	77.00**	2.592**	3.90**	3908249.1**	0.0204**
C*I	4	18.41 ns	5.90 ns	0.287 ns	8.00**	511513.0**	0.0029**
Y*C*I	4	31.91 ns	3.67 ns	0.165 ns	8.09**	108098.2**	0.0007**
Error	32	24.422	3.194	0.121	0.341	27056.3	0.00015
Coefficient of variation (%)		6.0	9.3	8.1	1.8	5.5	5.1

*, ** and ns significantly at 0.05, 0.01 and not significantly at this levels.

Table 2) Comparison of means of year, cultivar and irrigation method effects on plant height, number of pods per plant, number of seed per pod, 100-seed weight, grain yield and water productivity in common bean cultivars in Shahrekord in 2016 and 2017.

	Plant height (cm)	Number of pods per plant	Number of seed per pod	100-seed weight (g)	Grain yield (kg ha^{-1})	Water productivity (kg m^{-3})
Year						
2016	83.1 a	14.73 b	4.06 b	33.07 a	3044.9 a	0.230 b
2017	83.1 a	23.88 a	4.51 a	30.49 b	2901.5 b	0.247 a
Cultivar						
Koosha chitti bean	79.9 b	16.18 c	4.40 a	41.61 a	3053.4 b	0.248 b
Yaghut red bean	81.7 b	23.42 a	4.05 b	25.94 c	3269.0 a	0.261 a
Dorsa white bean	87.7 a	18.32 b	4.40 a	27.80 b	2597.2 c	0.206 c
Irrigation method						
I_1	81.9 b	17.73 b	4.15 b	29.89 c	2158.8 c	0.251 a
I_2	81.1 b	18.57 b	4.11 b	31.87 b	2850.3 b	0.209 b
I_3	86.3 a	21.62 a	4.59 a	33.59 a	3910.6 a	0.256 a

In each part and each column, means with the same letters have not different significantly at 0.05 level of Tukey's test.

Table 3) Comparison of means of interaction of cultivar and irrigation method on 100-seed weight, grain yield and water productivity in common bean in Shahrekord in 2016 and 2017 by using slice on cultivars.

Cultivar	Irrigation method	Grain yield (kg ha^{-1})	Cultivar	Irrigation method	100-seed weight (g)	Cultivar	Irrigation method	Water productivity (kg m^{-3})
Koosha chitti bean	I_1	2455.7 ^{c}	Koosha chitti bean	I_1	38.5 ^{c}	Koosha chitti bean	I_1	0.283 ^{a}
	I_2	2875.6 ^{b}		I_2	41.6 ^{b}		I_2	0.211 ^{c}
	I_3	3829.0 ^{a}		I_3	44.7 ^{a}		I_3	0.251 ^{b}
Yaghut red bean	I_1	2263.9 ^{c}	Yaghut red bean	I_1	24.3 ^{c}	Yaghut red bean	I_1	0.264 ^{b}
	I_2	2987.5 ^{b}		I_2	26.1 ^{b}		I_2	0.220 ^{c}
	I_3	4555.7 ^{a}		I_3	27.5 ^{a}		I_3	0.298 ^{a}
Dorsa white bean	I_1	1756.8 ^{c}	Dorsa white bean	I_1	26.9 ^{b}	Dorsa white bean	I_1	0.205 ^{a}
	I_2	2687.7 ^{b}		I_2	28.0 ^{a}		I_2	0.196 ^{a}
	I_3	3347.2 ^{a}		I_3	28.6 ^{a}		I_3	0.218 ^{a}

In each column and each cultivar, means with the same letters have not different significantly at 0.05 level of Tukey's test.

Table 4) Water consumption measured in irrigation method treatments of common bean cultivars in 2016 and 2017.

Irrigation method treatments	Water consumption rate (m^{3} ha^{-1})		
	2016	2017	Means of two years
I_1	85996 ^{c}	8798 ^{c}	8697 ^{c}
I_2	14546 ^{b}	12500 ^{b}	13523 ^{b}
I_3	15884 ^{a}	14700 ^{a}	15292 ^{a}

In each column, means with the same letters have not different significantly at 0.05 level of Tukey's test.

Irrigation method

As table 4 shows, water consumption rates in I2 and I3 irrigation methods were significantly higher than in I1 irrigation method. In I3 irrigation, which is a strip surface irrigation, there was the highest water use in both years. This indicates that strip irrigation had the highest water use and strip-drip irrigation had the lowest water use. About 60 percent of bean production worldwide is under water stress, and drought is the second leading cause of post-disease decline. Increasing the adaptability of bean genotypes to soil water shortages contributes to stability and expansion of production in drought-prone environments. Although the bean is not a drought-resistant species, it grows in a wide range of habitats exposed to seasonal droughts and widespread fluctuations in soil moisture in different years (Salehi, 2015a). An irrigation program is required for the optimum performance of the water unit. The critical and sensitive stage of growth is moisture deficiency, flowering and early pods covering 40 to 50 percent and 50 to 60 percent of the growing season, respectively. To achieve maximum yield potential, beans require 30 to 45 cm of moisture in the soil during the growing season. The cycle and amount of irrigation water depends on the stage of growth (determines daily water use), water holding capacity in the root zone, and climatic conditions (Salehi, 2015a). Irrigation management is probably the most important factor affecting the quantitative and qualitative yield of beans. Irrigation period of crop depends on growth, root development, soil water holding capacity and water consumption through evapotranspiration (ET). Daily ET and climate estimates, along with regular soil moisture readings, are important for accurate irrigation management (Salehi, 2015a). Researches and experiences showed that beans in loamy soil require 6 to 8 days of irrigation. The most practical way to describe bean irrigation is frequent but light. Water consumption (evapotranspiration) in beans is about 50 to 65 cm per season, depending on variety and production level. Water consumption includes the amount of water evaporated from the soil plus the amount of transpired from bean plants, and it does not include drained and out of the field water. Therefore, depending on the efficiency of the irrigation system, the amount of water used may vary from 65 to 100 cm year^{-1}, plus an additional 15 cm ha^{-1} for irrigation before planting (Salehi, 2015a). Beans are watered in different ways. Irrigation enhances the potential of grain yield and enables the farmer to produce inappropriate land. The used system is determined by the size and shape of the land, as well as access to labor and capital (Salehi, 2015b). Furrow irrigation is a common method, but sprinkler irrigation is used in some parts of the country, especially in shallow soils with high clay content. However, beans should be watered according to soil conditions and climatic conditions, regardless of the symptoms of water stress in the plant. When soil moisture is low enough to limit the rate of crop growth, plant color begins to darken. When watering is done, the color of the shade changes rapidly to light. The color difference between the water stress region and the humid region is well recognized in the fields. If the bean plants see a lot of water stress, the plants turn dark greenish-blue, the lower leaves begin to fall, and the flowers and small pods fall. If the beans are severely subjected to water stress during the growing season, they will have very low yields and quality, as weak plants are unable to recover after temporary water shortages (Salehi, 2015a).

Grain yield components

Seed yield components were significantly different in different cultivars (Table 2). The highest number of pods per plant was obtained from Yaghut red bean, the highest number of pods per plant consisted of Koosha chitti bean and Dorsa white bean, the highest 100-seed weight of Koosha chitti bean and the highest yield of Yaghut red bean. Pod number is one of the most important components of yield in determining bean yield. The yield of bean increased significantly on the basis of the quadratic relationship with increasing number of pods per plant. It has been reported that among the yield components, the number of pods per plant was often considered as an indirect selection criterion for increasing yield due to more and more consistent relationship with yield. It is also stated that grain yield is strongly correlated with the number of pods in beans. The pod is genetically controlled in the plant and is, of course, affected by environmental factors (Salehi, 2015a). The number of grains per pod and the 100-seed weight are important components of yield. These traits are strictly controlled hereditarily. However, both of these traits are affected by environmental conditions. The number of seed per pod varies from 3.1 to 6 with a mean of 4.4. It was reported that the number of seed per pod varied from 3 to 5.4 in two bean cultivars and in different plant populations. Also, 100-gseed weight is an important component of bean yield that has a significant linear relationship with grain yield. In a study conducted at the National Rice Center and the Brazilian Bean Research Center, there was a significant quadratic relationship between 100-grain weight and bean yield. The variability of grain yield due to 100-seed weight was 41% which indicates an increase in grain yield with 100-seed weight. The weight of one hundred grains is inherently controlled and also affected by environmental factors (Salehi, 2015a). The most important yield components and its related traits are pod number, 100-seed weight, number of pods per pod, shoot dry weight, leaf area index, nitrogen harvest index, and grain harvest index. Based on the experimental results and overview, the importance of yield components and related plant traits were as follows: pod number> Nitrogen harvest index> shoot dry weight> 100-seed weight> seed harvest index> seed number per pod. However, higher yield is only possible when there is a proper balance between these plant traits (Salehi, 2015a).

Bean cultivars

As Table 2 shows, the studied cultivars had differences in plant height, grain yield components, grain yield, and water use efficiency. Among the crops, bean shows the highest variation in growth habit, seed size, and maturity. In different bean gene pools, there is a wide genetic diversity in grain yield potential. Therefore, it is necessary to pay close attention to breeding indigenous populations to achieve maximum grain yield potential under optimal environmental conditions and to recombine the seed yield enhancer genes with the genes responsible for resistance to maladaptive factors (van Schoonhoven and Voysest, 1993). Bean varieties have differences in adaptation, growth habit, disease resistance, and other traits. There are different types of seed in different size, shape and color (Salehi, 2010). Bean varieties have differences in adaptation, growth, disease resistance, and vegetative and reproductive characteristics (van Schoonhoven and Voysest 1993; Graham and Ranalli, 1997; Fageria and Santos, 2008). Rafieiolhosseini et al. (2016) showed that white and chitti bean varieties had different responses to water stress. They stated that considering the value of water in agriculture and the existence of intermittent droughts in the country, saving on water use and optimum use of available water seems necessary and therefore it can be equally effective. By the same effect of 100% and 80% irrigation on bean seed yield, some irrigations can be eliminated in common bean cultivation. Genetic differences between different cultivars led to differences in their agronomic traits and caused their grain yield to differ under the same climatic conditions. Therefore, due to genetic differences in different climatic conditions, occurrence of different phenotypes (grain yield, number of pods per plant, 100-seed weight, etc.) is inevitable, and the difference between them is the result of genetic difference and their different response to the environment.

Water use efficiency

Water productivity in irrigation treatments varied (Table 2). The highest water use efficiency was obtained from I3, which was not significantly different from I1 treatment. This shows that strip-drip irrigation has less grain yield than strip surface irrigation, but its water productivity is comparable to that of surface irrigation, which has a much higher yield, and both methods have higher water productivity than the furrow irrigation method. Water use efficiency in different cultivars was also significantly different (Table 2). The highest water use efficiency was obtained from Yaghut red bean which was significantly different from other cultivars which could be explained by lower grain yield of other bean cultivars in this experiment.

Interaction of irrigation method and cultivar

In Koosha chitti bean, the highest seed yield and 100-seed weight were obtained from I3 irrigation method, which is justified in both years due to higher water consumption (Table 4). In this cultivar, the highest water productivity was obtained from I1 treatment, which shows that irrigation with strip-drip irrigation with 43.1% decrease in water consumption increased water productivity by 12.7% compared to surface irrigation. In Yaghut red bean, the highest grain yield and 100-seed weight were obtained from I3 irrigation method, which is justified in both years due to higher water consumption (Table 4). In this cultivar, the highest water productivity was obtained from I3 treatment, which was 11.4% higher than I1. This shows that the very good yield of this cultivar under strip irrigation conditions has been able to increase its water productivity, and the deficit with strip-drip irrigation cannot equal it, although it is in the second level. In Dorsa white bean, the highest seed yield and 100-seed weight were obtained from I3 irrigation method, which is justified in both years due to higher water consumption (Table 4). In this cultivar, the highest water productivity was obtained from I3 treatment, which was 5.9% higher than I1. This indicates that the high yield of this cultivar under strip irrigation conditions was able to increase its water productivity, although there was no significant difference between irrigation treatments in this cultivar. The foregoing indicates that different cultivars under the same conditions may have different responses to environmental conditions (Salehi, 2015a; van Schoonhoven and Voysest, 1993; Graham and Ranalli, 1997).

CONCLUSION

The results of combined analysis showed that plant height, number of seeds per pod, number of pods per plant, 100-seed weight, grain yield and water productivity were affected by bean and irrigation. Interaction of cultivar in irrigation had significant effect on 100-seed weight, grain yield, and water productivity. The highest grain yield was obtained from Yaghut red bean cultivar. The highest water productivity was obtained from Yaghut red bean cultivar. The highest grain yield was obtained by strip surface irrigation. The highest water productivity was obtained from strip surface irrigation, which was not significantly different from strip-drip irrigation, while water use in strip-drip irrigation was significantly lower than that of strip surface irrigation. Therefore, if the only objective was grain yield, surface strip irrigation was superior, which requires high water consumption, but if the goal was to reduce water consumption and increase water productivity, could considered strip-drip irrigation, although its grain yield was lower, but there was no significant difference between its water productivity with surface strip irrigation.

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