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EFFECT OF IRRIGATION ON YIELD AND YIELD COMPONENTS OF BEAN VARIETIES

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ABSTRACT
This experiment was conducted in Amlash County, Gilan Province, Iran, in 2013 to evaluate the effect of irrigation and varieties on yield and yield components of beans. The experiment had a split-plot with randomized complete block design and was performed in 3 replications with 2 treatments including irrigation procedures of I_1 = control (rainfed), I_2 = irrigation during vegetative growth phase, I_3 = irrigation during reproductive growth phase, I_4 = irrigation during vegetative and reproductive growth phase) and 3 local varieties of beans (V_1 = red streaks, V_2 = black streaks, and V_3 = simple). The results showed that irrigation had significant effects on plant height, pod length, number of pods per plant, number of seeds per pod, grain yield, and harvest index. The highest and the lowest grain yield were seen in the irrigation during vegetative + reproductive growth phase treatment and the rainfed treatment, respectively. Traits of plant height, number of pods per plant, number of seeds per pod, grain yield, biological yield, and harvest index were affected by the bean varieties. The simple and red streaks varieties had the highest and lowest yield, respectively. The interaction effect of the treatments on number of pods per plant, number of seeds per pod, grain yield, biological yield, and harvest index was significant.

KEYWORDS: irrigation, seed pod, variety, bean, harvest index.

INTRODUCTION

Legumes are the second source of human food (Bagheri *et al*., 1997). Beans are the most important members of legumes and given their high protein content and other desirable agronomic characteristics, they have the largest cultivation area among legumes. In Iran, beans are in the first place it terms of cultivation area and economic importance (Majnoon Hosseini, 1993). Cultivation area of beans was 29,234,227 ha for dry grain and the yield was 1,237,843 tons in 2013 in the world. This plant has the largest cultivation area among legumes. Bean cultivation area and grain yield were 98,000 ha for dry grain and 9310 tons, respectively (anonymous, 2013). Therefore, identification of improvement ways of plant yield and taking advantage of production factors, as well as selecting the proper cultivar are of great importance (Koochaki and Banayan Aval, 2007). An important factor in increasing the yield of bean is to select high-yield varieties which are tolerant to biotic and abiotic stresses (Ghanbari and Taheri Mazandarani, 2003). Different plants and even different varieties of plants respond differently to drought stress (Vieira *et al*., 1991). As one of the components of yield, seed weight has been reported to be influenced mainly by genotype (Ghanbari and Taheri Mazandarani, 2003). This suggests that the different varieties have genetically different potentials for seed weight. One of the most important environmental factors that determine the yield is soil moisture. In fact, irrigation is done in order to maintain the soil moisture at a desired status and to minimize the moisture stress exerted on the crop during the growing season (Kumudini *et al*., 2002). When grain yield is sought in crop production, the time of stress and stress severity acquire an equal importance (Sarmadnia and Koochaki, 2007). As reported by researchers, water scarcity results in reduced dry weight of aerial parts and reduction of assimilates (Bayat *et al*., 2010).

Researchers have demonstrated that water stress before flowering, pod formation, seed formation and even before harvesting decreases about 30% of beans yield and in general, irrigation from flowering to seed formation has been reported important in increasing grain yield (Samadi and Sepaskhah, 1984). Although low irrigation at different growth phases affects grain yield, some researchers suggest the higher effect of irrigation on some phases than others. Regarding the effect of drought stress on yield and yield components of beans varieties, researchers stated that the mean yield in stress-free status, stress during the whole growing season, and stress during the vegetative and reproductive periods were 17.9, 10.44, 14.19, and 9.62 grams per plant, respectively (Dadkhah and Aminin Dahaghi, 2012). It was also reported that drought stress reduces yield and yield components of beans both in flowering and grain filling phases (Boutraa and Sanders, 2001). The present experiment investigated the effect of irrigation on yield and yield components of beans varieties.

MATERIALS AND METHODS

This experiment was conducted in Amlash Rankooh region, Gilan Province, Iran, in the spring and summer 2013, in a split-plot with randomized complete block design with 3 replications and 2 treatments including irrigation and variety. The main factor was irrigation area including I_1 = control (rainfed), I_2 = irrigation during vegetative growth phase, I_3 = irrigation during reproductive growth phase, I_4 = irrigation during vegetative and reproductive growth phase) and the subsidiary factors were 3 local varieties of beans (Pach-Baghla) (V_1 = red streaks, V_2 = black streaks, and V_3 = simple). The plots were 6.75 m in width and 2.5 m in length, and the plants were cultivated in each plot in 5 rows with 50 cm distance; the spacing between the plants was 10 cm. A row was leaved uncultivated in the treatments; the distance between 2 replications was set to 2 m. Planting was performed manually in 24 May through furrow cultivation. Meteorological data required for the study were obtained from the meteorological station of Roodsar. Weather information of the region during the growing season of bean was shown in Table 1.

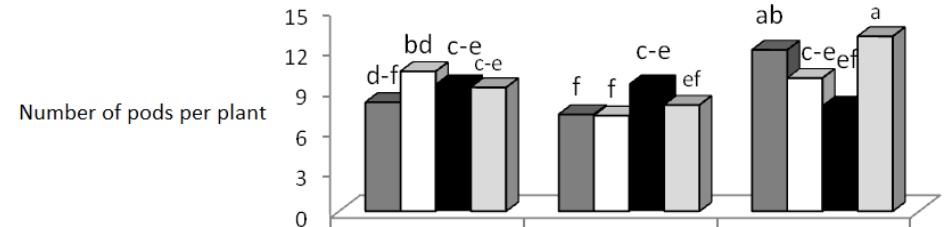
Table 1. Weather data experiment field.

	May-Jun	Jun-Jul	Jul-Aug	Aug-Sep
Precipitation (mm)	28.8	24.2	93.8	101.1
sunlight hours (hr)	274.9	265.4	113.4	178.6
Mean humidity (%)	76	71	81	77
Evaporation (C°)	128.5	160.7	87.4	90.2
Maximum temperature (C°)	27.1	29.7	28	28.4
Maximum temperature (C°)	19.3	21.1	21.6	21.2

To determine the physical and chemical characteristics of the soil, different parts of the experimental field soil were randomly sampled from surface to 30 cm depth and composite samples were prepared through their blending; the results are presented in Table 2. At the end of the growing season, 10 plants were harvested from each plot and their plant height, pod length, number of pods per plant, number of seeds per pod, grain yield, biological yield, and harvest index were determined. Statistical analysis was performed using SAS; the treatments means were compared with Duncan's test; and graphs were plotted using Excel 2007.

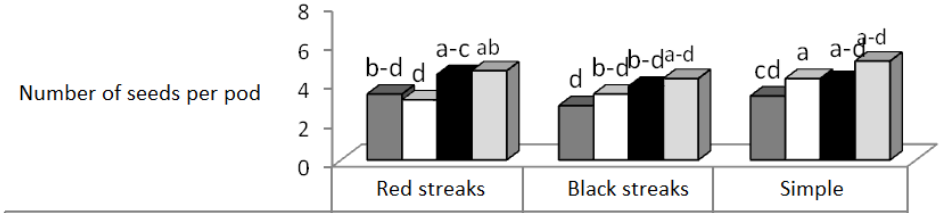
RESULTS

The analysis of variance showed that the effect of different levels of irrigation and plant variety on plant height was significant at the level of 1%, while the interaction effect of the irrigation and variety treatments on plant height was not significant (Table 3). According to the means comparison chart, the highest height of the plants, with an average of 50.5 cm, was seen in the irrigation during vegetative growth phase, and vegetative + reproductive growth phase treatments, which were in the same group as the treatment of irrigation during reproductive growth phase (47.9 cm). The shortest plant was observed in the rainfed treatment with an average of 43.8 cm (Table 4). The highest plant was seen in the simple variety bean with an average 53 cm, and the shortest in the red streaks with an average of 45.6 cm, which had no significant difference with the black streaks (Table 5). The results of analysis of variance showed a significant effect of various irrigation levels on bean pod length, while the impact of bean varieties and treatments interaction on bean pod length was not significant (Table 3). The longest pod was seen in the treatments of irrigation during vegetative + reproductive growth phase and irrigation during reproductive growth phase with a mean of 12.1 cm. The shortest pod was seen in the irrigation during vegetative growth phase with a mean of 10.4 cm. The rainfed treatment had no significant difference with other treatments (Table 4).



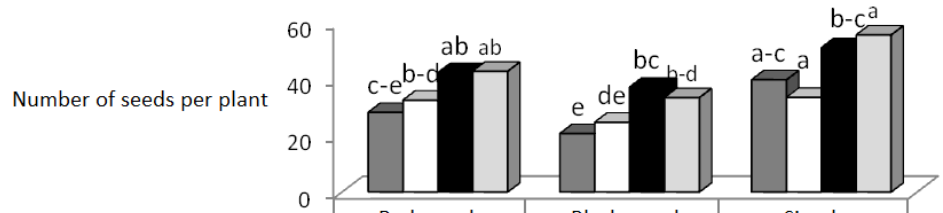
	Red streaks	Black streaks	Simple
Control	8,1	7,2	12
Irrigation during vegetative growth phase	10,4	7,1	9,9
Irrigation during reproductive growth phase	9,5	9,5	7,9
Irrigation during reproductive and vegetative growth phase	9,2	7,9	13

Figure 1: Interaction effect of the irrigation and varieties treatments on the number of pods per plant



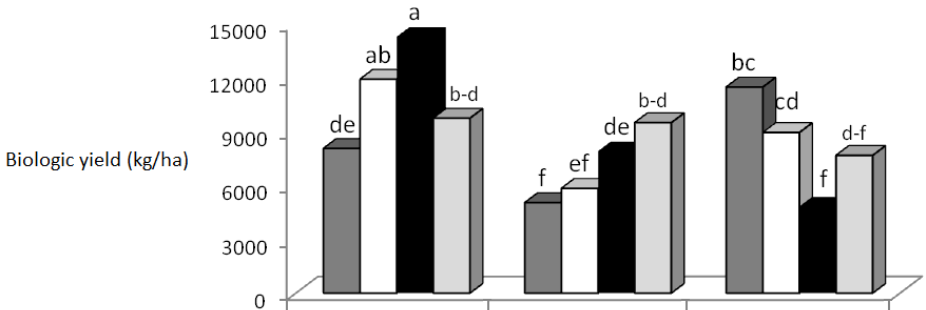
	Red streaks	Black streaks	Simple
Control	3,4	2,8	3,3
Irrigation during vegetative growth phase	3,1	3,4	4,2
Irrigation during reproductive growth phase	4,4	3,8	4,1
Irrigation during reproductive and vegetative growth phase	4,6	4,2	5,1

Figure 2: Interaction effect of the irrigation and varieties treatments on the number of seeds per pod



	Red streaks	Black streaks	Simple
Control	28,1	20,6	39,6
Irrigation during vegetative growth phase	32,4	24,6	33,4
Irrigation during reproductive growth phase	42,1	37	50,9
Irrigation during reproductive and vegetative growth phase	42,6	33,3	55,4

Figure 3: Interaction effect of the irrigation and varieties treatments on the number of seeds per plant



	Red streaks	Black streaks	Simple
Control	8049,5	5033,4	11471,5
Irrigation during vegetative growth phase	11907,2	5826,4	8941,7
Irrigation during reproductive growth phase	14273,7	7901,8	4823
Irrigation during reproductive and vegetative growth phase	9737	9485,8	7664,7

Figure 4: Interaction effect of the irrigation and varieties treatments on biological yield of the beans

According to Table 3, the effect of irrigation, varieties, and treatments interaction on the number of pods per plant was significant at the level of 1%. The simple variety with irrigation during vegetative + reproductive growth phase had the highest number of seeds per pod, averaging 13.8 seeds. The lowest number was seen in the black streaks variety with irrigation during vegetative growth phase and the rainfed treatments with means of 7.1 and 7.2 seeds, respectively (Fig. 1).

Different phases of irrigation and treatments interaction had a significant effect on the number of seeds per pod at the level of 1%, while the effect of different varieties of bean on the number of seeds per pod was significant at the level of 5% (Table 3). The simple variety with irrigation during vegetative + reproductive growth phase resulted in the highest number of seeds per pod, and the lowest number was seen in the black streaks variety without irrigation and the red streaks variety with irrigation during vegetative growth phase (Fig. 2).

The effect of different levels of irrigation on the number of seeds per plant was significant at the level of 5% and the effect of varieties and the treatments interaction of different irrigation phases and variety on the number of seeds per plant was significant at the level of 1% (Table 3). The simple variety with irrigation during vegetative and reproductive growth phase and irrigation during reproductive growth phase had the largest number of seeds per plant and the black streaks variety without irrigation had the lowest number (Fig. 3).

Analysis of variance showed that irrigation had a significant effect on grain yield at the level of 5% and different varieties of bean had significant effects on grain yield at the level of 1%. The treatments interaction effect in different phases of irrigation was not significant (Table 3), suggesting that each factor has affected grain yield independently. According to the means comparison chart, the highest grain yield was obtained in irrigation during vegetative + reproductive growth phase with an average of 3334.8 kg/ha, and had no significant difference with irrigation during reproductive growth phase; they were statistically in the same group. The lowest grain yield was seen in the rainfed treatment with an average of 1877.2 kg/ha. The treatment of irrigation during vegetative growth phase was between these two groups and had no significant difference with them (Table 4). The simple variety had the highest grain yield with an average of 3879.9 kg/ha and the red streaks variety was statistically the next. The black streaks with an average of 1610.4 kg/ha showed the lowest yield (Table 5).

As seen in Table 4, different phases of irrigation had no significant effect on biological yield, therefore, no significant difference existed between different irrigation phases in terms of biological yield, and all treatments were in the same statistical group. The effect of different varieties of bean and treatments interaction of different phases of irrigation on biological yield was significant at the level of 1% (Table 3). The highest and lowest biological yield was observed in

the red streaks variety with irrigation during reproductive growth phase with an average of 14273.7 kg/ha and the black streaks variety without irrigation with an average of 5033.4 kg/ha, respectively (Fig. 4).

Table 2. Soil physical and chemical properties experiment field.

Source of variation	df	plant height	pod length	number of pod in plant	number of seed per pod	number of seed per plant	seed yield	biologic yield	harvest t index
(block)	2	3.87	5.07	1.74	0.08	65.67	265657.23	2094994.4	**96.99**
factor A (Irrigation)	2	97.34**	5.41**	1.85**	1.95**	270.13*	6508449.33*	1306929.2	**1093.96****
Error A	4	10.98	1.54	1.79	0.16	63.55	1447375.53	1615692.1	**369.25**
Factor B (Cultivar)	3	196.18**	0.11	20.80**	0.96*	678.26**	15629516.08**	48537959**	**2300.59****
AB	6	25.81	1.13	8.98**	0.95**	157.39**	3043340.43	27637757.7**	**360.98**
Error A	6	53.52	1.22	0.50	0.16	10.59	702674.38	235538.1	**281.60**
Error	12	16.77	0.93	0.55	0.21	21.21	864188.34	1100473.5	**167.26**
CV (Percent)		**8.50**	**8.34**	**8.10**	**11.75**	**12.70**	**13.01**	**11.85**	**18.60**

* and**: significant at 5% and 1% probability levels, respectively.

Table 3. Analysis of variance on plant height, pod longitude, number of pod in plant, number of seed per pod, number of seed per plant, seed yield, biologic yield and harvest index bean (Mean Squares).

Sampling depth (cm)	pH ($ds.m^{-1}$)	EC	Organic carbon (%)	Total Nitrogen (%)	P (mg/kg)	k (mg/kg)	soil texture
0-30	6.96	0.47	4.21	0.35	150.20	987	**loam**

Table 4. Mean comparison on plant height, pod longitude, seed yield and harvest index bean

Irrigation	plant height (cm)	pod length (cm)	seed yield (Kg.ha)	harvest index (%)
control (dryland)	43.8 b	11.6 ab	1877.2 b	**21.8 b**
vegetative growth stage	50.5 a	10.4 b	2342.7 ab	**27.4 ab**
reproductive growth stage	47.9 a	12.1 a	3707.6 a	**46.6 a**
vegetative and reproductive stage	**50.5 a**	**12.1 a**	**3334.8 a**	**38 ab**

Table 5. Mean comparison on plant height, seed yield and harvest index bean.

Cultivar	plant height (cm)	seed yield (Kg.ha)	harvest index (%)
red line	45.6 b	2956.4 b	**27.7 b**
black line	46.1 b	1610.4 c	**23.4 b**
no line	**53 a**	**3879.9 a**	**49.2 a**

Changes in different phases of irrigation and different varieties had significant effect on harvest index of beans. The interaction effect of different irrigation treatments and bean varieties on harvest index was not significant (Table 3). The highest harvest index with a mean of 38% was seen in irrigation during vegetative + reproductive growth phase which was in the same group with irrigation during vegetative growth phase. The lowest harvest index with a mean of 21.89% was obtained in the rainfed treatment. The treatment of irrigation during vegetative growth phase was placed between these two groups (Table 4). The highest harvest index was obtained from the simple variety with a mean of 49.2% and the lowest from the black streaks variety, with an average of 22.4%, and without a significant difference with the red streaks variety (Table 5).

DISCUSSION

As mentioned in the results, plant height increased with irrigation in comparison to rainfed conditions. Researchers stated that stress in the vegetative phase results in the shortest plants with low grain yield. The draught stress affects morphological, physiological and phenological traits of beans (Nielsen and Nelson, 1998). Eskandari *et al.* assessed water use efficiency and grain yield of sesame varieties in different irrigation conditions and reported that plant height and grain yield reduced with increasing water stress (Eskandari *et al*., 2010). In this experiment, the simple bean variety had higher height than others; this can be due to the genetic trait of this variety. Researchers studied bean yield components and showed that there are genetic additive effects on plant height (Dimova and Svetleva, 1993). The longest bean pod was seen in irrigation during vegetative growth phase and irrigation during vegetative + reproductive growth phase. Given the short growing season for beans, sufficient water should be available to plants for good performance (Poor Elam, 1992). There was no significant effect of the different varieties on pod length. Researchers studied bean yield components and showed that there are genetic additive effects on pod mean length (Dimova and Svetleva, 1993).

In this experiment, the number of seeds per pod reduced in rainfed conditions. Stress during pollination and fertilization decrease seeds number due to pollen dehydration. In addition, drought stress affects pollen and pollen tube growth in the style, as well as ovary and egg. Wilt stigma also prevents the growth of the pollen tube. The effect of stress during grain filling is obvious, because the potential yield depends on the weight and number of seeds, and requires complete pollination and accumulation of assimilates in the seed. Compounds accumulated in seeds are provided through photosynthesis and transfer nutrients from other parts of the plant (Bagheri Kumar Olia, 1996). Water stress during grain formation was reported to be more important than the other phases of growth (Calvache *et al*., 1979). Researchers reported that irrigation increases the number of seeds or pods in soybean branches (Ramseur *et al*., 1986). Grain yield was higher in irrigation during vegetative + reproductive growth phase and reproductive growth phase than other treatments. In agriculture, the highest economic yield of a product is achieved when equilibrium is established between the plant and environmental factors during the life cycle (Aniol, 2002). Yield is more affected when water scarcity occurs at flowering and pod formation stages in comparison with other stages (Mackay and Evans., 1962). Water scarcity during flowering and grain filling reduces yield and seed weight and results in early puberty of the beans (Singh, 1995). It was also reported that drought stress reduces yield and yield components of beans in flowering and grain filling stages (Boutraa and Sanders, 2001). According to research, drought stress in beans during flowering and grain filling results in decreased yield and accelerated maturity (Nielsen and Nelson, 1998).

Red streaks beans had higher biological yield than the other varieties, due to the variety's properties. In fact this variety had higher grain yield than other studied varieties, resulting in increased biologic yield. Bean harvest index was higher in the treatments of irrigation during vegetative + reproductive growth phase and irrigation during reproductive growth

phase than the other treatments. Given that the biological yield had no significant difference among different irrigation treatments, increased biological yield can be attributed to allocation of more assimilates in the reproductive organ. In these conditions, assimilates are more likely to transfer to the reproductive organs, rather than contributing in the vegetative growth and formation of stem and structural tissues. In this experiment, the simple bean had higher harvest index than the other varieties. The reason may be smaller plants (less biological yield) and further increase in plants' seeds number. Since the harvest index indicates the allocation of assimilates to seeds, efforts should be aimed at increasing the harvest index through agricultural operations. Although a larger harvest index does not guarantee a higher yield, it is a requirement for achieving the desired index (Hatami, 2001).

CONCLUSION

According to the results, the treatments of irrigation during vegetative + reproductive growth phase and irrigation during reproductive growth phase were determined as the most appropriate irrigation treatments; and with regard to saving water, reducing production costs without a significant decrease in yield, and creating balance between water consumption and yield, the treatment of irrigation during reproductive growth phase could be more appropriate; this requires extensive studies. Despite the adverse effects, stress during beans vegetative phases will not result in a significant reduction in grain yield, but water stress during reproductive phase will greatly reduce plant yield. Therefore, it is recommended to resolve this critical period through providing favorable conditions for the plant. Between the studied varieties, the simple bean had a higher yield than other varieties showing its greater adaptation to environmental conditions in the region.

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