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The effect of drought stress and different levels of potash fertilizer on yield components of broad bean

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Abstract

In order to study the effect of drought stress and different levels of Potash Fertilizer on yield components and growth trend of broad bean a split plot experiment in randomized complete block design with four replications was carried out in Ahwaz weather conditions. Main factors of experiment included irrigation is (A_1: perfect irrigation regime all seven days during the plant growth period, A_2: 14-day irrigation interval, A_3: 21-day irrigation interval) and the sub factor included three levels of potash fertilizer (B_1: control, B_2: 50kg potassium sulfate per hectare, B_3:100kg potassium sulfate per hectare). Results showed that the use of potassium sulfate had a significant effect on the number of grains per plant, number of pods, grain yield, and biological yield of broad bean, but its effect on the harvest index was insignificant. The highest number of grains per plant and the highest number of pods were obtained in control irrigation level and use of 50kg potassium sulfate per hectare. The highest grain yield was obtained by the use of 100 kg potassium sulfate per hectare and control irrigation. The highest biological yield belonged to control irrigation and the use of 50kg and 100 kg potassium sulfate per hectare. The highest harvest index belonged to the control irrigation. Generally, it could be concluded that it is possible to harvest a remarkable yield by using 50kg potassium sulfate and seven-day irrigation interval with regard to regional and nutritional conditions of broad bean.

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Introduction

Grains beans with 12% to 32% protein play an important role in supplying protein that human needs and are considered as natural food supplement for cereals in human nutrition (Majnun Hosseini, 1997). Vicia Faba is daily increasing as one of the oldest crops due to different reasons such as its rich protein on one hand, and the desire for self-sufficiency and variety in agricultural systems and the increasing cost of livestock feed, on the other hand. In modern agriculture, broad bean is considered as a low cost crop with little need to fertilizer and easy control of pests and diseases. To achieve maximum yield, the sufficient and balanced amounts of nutrients are necessary in the distribution of broad bean roots. Lack of macronutrients such as phosphorus and potassium has a negative effect on the growth and nitrogen fixation rate of crops (Sabaghpoor, 1993).

In the last two decades, water scarcity has led to the restriction of crops yield. Recently, a lot of efforts have been made around the world to produce drought tolerant cultivars (Foroud and Mundel, 1993). One possible way to increase the yield in such conditions is to determine the need of plant to fertilizer and water under drought stress when the plant has lower yield (Sneller and Dombek, 1997).

Ramseur *et al.* (1984) reported that irrigation increased the number of grains or the number of pods per branch in soybeans. Mahler *et al* (1995) observed that 90 kg potassium per hectare significantly increased the yield and weight of 100-grain soybean. These effects require sufficient irrigation during the flowering stage.

By applying 0, 40, 80, 120, and 160 kg potassium oxide ha^{-1} to the Hobbit cultivar of soybean, Azizi (1998) concluded that by increasing the use of potassium fertilizer the negative effect of water stress was adjusted and the grain yield increased. He claimed that if the soybean were exposed to moisture stress but had more access to the soil potassium, it could compensate for the decrease of yield caused by the stress via increasing the weight of grains in sub branches.

Drought stress in early stages of reproductive growth may lead to the increasing loss of flower and pod (Korte *et al.*, 1993). Habibzade Tabari (2003) showed that the main effect of various levels of potassium fertilizer on yield, number of pods per plant, and weight of 1000-grain was statistically significant. Beiknejad (2007) used 0, 100, and 200 kg potassium ha^{-1} from the source of potassium sulfate in three genotypes and concluded that as the use of potassium increased, the grain yield and the number of grains in the main pods significantly increased. In another experiment it became clear that the highest grain yield of the soybean was due to the use of solo potash fertilizer. The use of solo potash increased the number of grains per pod, the number of sub branches, and the weight of grain as well.

Materials and methods

The experiment was carried out in the experimental filed of Islamic Azad University of Ahwaz in the fall of 2011 to examine the interactive effects of drought stress and different levels of potash fertilizer on growth and yield components of broad bean under weather conditions of Ahwaz. It was a split plot experiment in randomized complete block design with four replications which began in Dec 1, 2011 and lasted for five months. Main factors of experiment included irrigation periods ($A_{1:}$ perfect irrigation regime all seven days during the plant growth period, A_2: 14-day irrigation interval, A_3: 21-day irrigation interval) and the sub factor included three levels of potash fertilizer (B_1: control, B_2: 50kg potassium sulfate per hectare, B_3:100kg potassium sulfate per hectare). The whole nitrogen fertilizer as much as 75kgha^{-1} and the entire phosphorus fertilizer as much as 50kgha^{-1} were added to the land as the basis of plough. In order to determine the tissue and the fertilizer need of the soil samples were taken from 15-30 and 30-60 cm of the soil before cultivation. Land preparing operation was done in early fall (September) and in October the broad been seeds were planted by hand. Two levels of potassium that is

50 and 100 kgha-1 were added in pre-eruptive phase. Each plot was as big as 4×5m with 8 lines each one 5m long and as far as 50cm from each other and the distance between every two plots was 1m and the distance between plants per row was 20cm. All statistical calculations were done by means of SAS software in this experiment. Diagrams and tables were drawn by Excel and Word software. First, the variance of the measured traits was analyzed and then the means of the studied traits were compared via Duncan's multiple range tests at 0.05 error probability level.

Results and discussion

Number of Grains per Plant

The results of the ANOVA showed that the interactive effect of various levels of fertilizer and irrigation on the number of grains per plant was significant in broad bean (Table 1). Considering the means comparison results, in control treatment irrigation, different levels of potassium fertilizer caused a significant difference in comparison to the control one. With the beginning of drought stress and increasing irrigation period (14-day irrigation interval) the treatment with 100kg potassium sulfate fertilizer led to the increase of the number of grains per square meter. In maximum drought stress conditions (21-day irrigation interval) the use of 50kgha-1 potassium sulfate improved the number of grains in broad bean. In the control irrigation treatment, by increasing the use of potassium, with regard to the fact that the crop was not under water stress, the plant height increased which led to the increase of sub branches and also the increase of grains per plant. By the beginning of drought stress, the increase of potassium consumption overcame the negative effects of water deficit and the maximum number of grains per plant was achieved in 100 kg treatment. However, the increase of water stress caused the significant decrease of grains per plant in control fertilizer treatment and in two other treatments with the same water deficit but with more potassium was able to adjust the effect of water deficit. In other words, as potassium increased in the plant, ATP production, which in necessary for loading photosynthetic materials by phloem, increased and the effects of water deficit in such conditions were observed less and less (Mojtahedi and Salari, 1988).

Table 1. The results of the ANOVA of yield components.

Means of square							Sources
Harvest index	Biological yield	Grain yield	Pod length	Number of pods	Number of grains per square meter	Freedom degree	
3/57	**112538/12**	**322452/48**	**4/58**	**68/85**	**19448/3**	3	Block
14/56*	**362123/24****	**1053982/32****	**18/94 ****	**482/05 ***	**55415/1 ****	2	Irrigation interval
2/41	**72514/66**	**226829/35**	**2/44**	**175/71**	**17331/6**	6	Error A
9/834	**612547/45***	**20889/85****	**19/92 ****	**906/75 ****	**46066/1****	2	Levels of Potassium sulfate
3/55	**21879/54**	**186894/48**	**10/87 ***	**409/22 ***	**39676/2****	4	Interactive effect
13/14	**123549/37**	**239844/63****	**2/74**	**120/81**	**6552/4**	18	Error B
9/64	**14/57**	**11/55**	**10/71**	**6/85**	**13/20**		CV%

Number of Pods

The results of the ANOVA showed that the effect of different levels of fertilizer and irrigation and their interactive effect on the number of pods in broad bean were significant (Table 1). With regard to the means comparison results, in control irrigation, different levels of potassium fertilizer have significant difference in comparison to the control treatment. With the beginning of drought stress and the increase of irrigation period of mild deficit irrigation treatments (14-day irrigation interval) and severe deficit irrigation treatments (21-day irrigation interval), the use of 100 kg potassium sulfate ha^{-1} increased the number of pods in broad bean. Probably in drought conditions, in spite of the fact that the plant has been in water deficit conditions the high concentration of the soil potassium has increased the level of K in leaves and consequently the plant has been able to sort of compensate for the negative effects of stress through the increase of the soil potassium via the increase of photosynthesis and ultimately has led to the increase of sub branches and number of pods in the plant (Mozafari, 1994, Azizi, 1998).

Table 2. Means comparison of the interactive effects of the number of grains per square meter, number of pods, and length of pod at different levels of irrigation s and potassium sulfate fertilizer.

Traits mean			treatments	
Pod length (Centimeter)	Number of pods (per plot)	Number of grains per square meter	Level of potassium sulfate ($kgha^{-1}$)	Irrigation interval
15.86 abc	*142 bcd*	*606 bc*	*0*	7days
16.62 ab	*220 a*	*795 a*	*50*	
17.25 ab	*167 abc*	*659 abc*	*100*	
13.58 cd	*154 bc*	*592 bc*	*0*	14 days
15.87 abc	*147 bcd*	*508 cd*	*50*	
17.50 a	*199 ab*	*701 ab*	*100*	
12.50 d	*93 d*	*427 d*	*0*	21 days
15.27 abc	*140 cd*	*641 abc*	*50*	
14.50 bcd	*181 abc*	*591 bc*	*100*	

Statistically, there aren't any significant differences between the means of treatments which have similar letters based on Duncan's multiple range test (5%).

Pod Length

The results of the ANOVA showed that different levels of fertilizer are significant for this trait (Table 1), but the effect of irrigation and the interactive effect on the pod length were not significant. Means comparison results showed that the use of potassium sulfate fertilizer (50, 100 $kgha^{-1}$) has caused a significant difference between them and the control treatment. Irrigation didn't have a significant effect on the pod length. These results are consistent with the findings of Yousefi *et al.* (2011). The lack of potassium in plant (control) resulted in early loss of the leaves which increased during the grain filling and led to the leaves' getting yellow and their premature aging. This phenomenon causes the disruption in assimilate transfer to the grain which is filling and thus leads to hollow pods and consequently decreases the length of broad bean pod (Azizi, 1998).

Table 3. Means comparison of simple effects of different levels of irrigation s and potassium sulfate fertilizer on the number of grains per square meter, number of pods, length of pod in broad bean.

	Traits mean		treatments
Harvest index	Biological yield	Grain yield	Irrigation interval
49 a	10/38 a	4/98 a	7days
44 ab	9/24 b	4/25 ab	14 days
40 b	7/07 c	3/18 b	21 days
			Levels of potassium sulfate
43 a	9/58 b	3/27 c	0 $kgha^{-1}$
45 a	10/93 a	4/12 b	50 $kgha^{-1}$
44 a	10/77 a	4/92 a	100 $kgha^{-1}$

Statistically, there aren't any significant differences between the means of treatments which have similar letters based on Duncan's multiple range test (5%).

Grain Yield

The results of the ANOVA showed that the levels of irrigation and fertilizer were significant for this trait (Table 1), but the interactive effects were not significant. Means comparison results showed that there was a significant difference between control irrigation period(7 days irrigation) and severe deficit irrigation, so that the highest grain yield in control irrigation was 4.98 $Tonha^{-1}$ and the lowest grain yield in sever deficit irrigation was 3.18 $tonha^{-1}$. It seems like that in the control treatment, due to production of more sub branches and thus the production of more pods in the plant in comparison to the severe deficit irrigation the grain yield increased in that treatment (Daneshian *et al.*, 2009). In other words, under sever deficit irrigation with regard to the decrease of soil wet, the number of flowers which change to the pods would decrease, fewer number of grains are produced in the pod and the size of produced grains is smaller which ultimately leads to the decrease of grain yield(Ramseur *et al.*, 1984). The increase of grain yield is resulted from the use of potassium sulfate which decreases the negative effect of deficit irrigation on broad bean. In other words, if the broad bean is exposed to moisture stress but has more access to the soil potassium, it might sort of compensate for the decrease of yield resulted from the stress by increasing the grain weight in sub branches (Tabari, 2003).

Biological Yield

The results of the ANOVA showed that levels of irrigation and fertilizer were significant for this trait (Table 1), but the interactive effect was not significant. The highest biological yield was obtained in control treatment (7-day irrigation interval) as much as ..... and the lowest biological yield belonged to the severe deficit irrigation (21-day irrigation interval) as much as ..... . The increase of deficit irrigation severity led to the decrease of plant photosynthesis and consequently the decrease of assimilates production in plant, so that the irrigation-off stress during the flowering stage and pod development stage reduced the number of pods in plant and the number of grains per pod. In other words, drought stress makes plant factors, which affect the cell development and division, decrease the plant biomass production (Pandy *et al.*, 1984). Moreover, the use of potassium sulfate increased the broad bean biological yield. It could be said that the lack of potassium in plant leads to the early loss of leaves which is increased during the grain filling stage and results in the leaves' getting yellow and plant's premature aging and ultimately leads to the decrease of plant biological yield (Mozafari, 1994; Azizi, 1998).

Harvest Index

The results of the ANOVA showed that only the levels of irrigation were significant for this trait (Table 1), but the effect of different levels of fertilizer and the interactive effect were not significant. The highest harvest index was obtained in the control treatment (7-day irrigation) as much as ..... and the lowest harvest index was obtained in severe deficit irrigation (21-day irrigation) as much as ..... .It could be said that under stress conditions, less photosynthetic material is produced in the plant and vegetative and reproductive growth and consequently the grain yield has decreased under water stress (Daneshian *et al.*, 2009). The reason of the insignificant effect of potassium sulfate on the harvest index could be possibly due to the effect of this fertilizer on grain yield and consequently on the biomass yield of broad bean (Grove *et al.*, 1987). In other words, after the use of potassium fertilizer both grain yield (economic yield) and biological yield (biomass) increased which resulted in no effect on the harvest index.

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