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ORIGINAL ARTICLE

Effects of irrigation disruption and Barvar-2 phosphate biofertilizer on Agronomic Characteristics of Sesame (Sesamum indicum L.)

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In order to evaluate the effects of irrigation disruption and Barvar-2 phosphate biofertilizer at different stages of growth on Agronomic Characteristics of Sesame, An experiment was conducted as split plot based on randomized complete block design with three replications in Salmas city, northwest of Iran, during spring of 2016. The main plot was Barvar-2 phosphate biofertilizer at two levels (control or non-biofertilizer and Barvar-2 phosphate biofertilizer) and irrigation disruption as the sub-factor in five levels including control or not irrigation disruption, irrigation disruption at 10 leaf stage, irrigation disruption at flowering stage, irrigation disruption at capsule formation stage, irrigation disruption at grain filling stage was considered. Results indicated that effect of Barvar-2 phosphate biofertilizer on Number of branches per plant, number of capsules per plant, number of seeds per capsule, seed oil percent and seed yield has been significant. The maximum seed yield at 1726.03 kg.ha-1 was observed in Barvar-2 phosphate biofertilizer. Effect of irrigation disruption on Plant height, number of branches per plant, number of capsules per plant, seed number per capsule, seed oil percent and seed yield has been significant. The highest seed yield (1985 kg.ha-1) was observed in control or non irrigation disruption treatment, which did not show significant difference with irrigation disruption treatment at 10 leaf stage. In order to save water irrigation disruption can be recommended at this stage of growth, especially in low water areas. The minimum seed yield was observed at 1214 kg.ha-1 in irrigation disruption treatment at flowering stage.
Keywords: Grain yield; Harvest index; Sesame; Fertilizer

Introduction

Sesame (Sesamum indicum L.) is one of the oldest cultivated plants in the world and the most important ancient oilseeds crop known to mankind. It belongs to family Pedaliaceae (Kaliyamoorthy et al. 2015). Sesame is an important source of edible oil and is widely used one of the ingredients in food products especially in bakery foods and animal feed (Beetti et al., 2006). Sesame is drought tolerant, but as with every crop will do better with more moisture (Ray Hansen, 2011). Drought and stresses from it are one of the most important environmental stresses that limit agricultural production and reduce the efficiency of using dry areas (Naseh Ghafouri et al., 2010). Among non-biological stresses, dryness is one of the non-biological environmental factors that limits the production of crops and reduces the average yield sometimes to 50% or more (Wang et al., 2003). Research shows that the performance of different crops is different in terms of amount, water intake intervals and growth stage and usually decreases with increasing drought stress (Paknejad et al., 2007). Water stress at the flowering stage of sesame through the abnormal development of embryonic bag, pollen seed sterilization can result in severe reduction of yield (Farahbakhsh and Farahbakhsh, 2014). Gauthier et al. (2001) also declared the stage of reproductive growth as the most sensitive stages of sesame plant growth to drought stress. Monasah et al. (2006) showed that drought stress leads to growth cessation, decline in dry matter , leaf number and Sesame seed yield. Dilip et al. (1991) studies on sesame seeds showed that the least yield of sesame seeds was observed at the irrigation disruption stage at flowering stage. Gine et al. (2010) also stated that the most sensitive stages of sesame growth are drought stress during flowering and seed filling. Ditta et al. (2000) showed that with drought stress, the number of capsules in sesame plant decreases. Omidi (2009) in the study of the effect of drought stress in different stages of safflower growth showed that by stopping irrigation after the end of the flowering stage or the beginning of seed filling, while the seed yield does not decrease significantly, water consumption is also saved. Biological fertilizers are made up of useful microorganisms that are produced, for example, for fixation of nitrogen and release of phosphate, potassium, iron, etc. These microorganisms are usually located around the root and help the plant in absorb the elements (Wu et al., 2005). Now it is certain that these microorganisms have more than one role, that is, in addition to helping to absorb a particular element, attract other elements, reduce diseases, improve soil structure, stimulate more plant growth and increase the quantity and quality of the product and increase the resistance of the plant to environmental stress (Naganda and colleagues, 2010). Bio-fertilizer (Phosphate Barvar2) has two phosphate solubilizing bacteria of the species Bacillus lenthus and Pseudomonas potida, which, by secretion of organic acids and acid phosphatase, dissolves insoluble phosphorus compounds and, therefore, can be absorbed into the plant (Boland nazar et al., 2014). Kumar et al. (2009) stated that application of biofertilizers with lower percentage of chemical fertilizers on sesame plant significantly increased plant height, grain yield and oil yield. Ghoosh and Mooyuddin (2000) reported that the application of biological fertilizers on sesame plant significantly increased plant height, number of branches, number of capsules per plant, 1000 seed weight and grain yield. According to Nasrollahzadeh Asl (2017), seed fertilization with Bio-fertilizer (Phosphate Barvar2) increased the yield of oil and sesame seeds. This research was conducted to investigate the effect of irrigation disruption and Bio-fertilizer (Phosphate Barvar2) on increasing grain yield and sesame oil in Salmas climate.

Materials and methods

This research was carried out in the spring of 2016 at Salmas Agricultural Office, northwest of Iran. Height of this region is 1344 meters above sea level and longitude and latitude are 44°52E, and 38°10N. The soil characteristics of experimented farm were a loam soil with a pH of 8.13 (Table 1). The experiment was conducted as split plot based on randomized complete block design with three replications. The main plot was Barvar-2 phosphate biofertilizer at two levels (control or non biofertilizer and Barvar-2 phosphate biofertilizer) and irrigation disruption as the sub-factor in five levels including control or not irrigation disruption, irrigation disruption at 10 leaf stage, irrigation disruption at flowering stage, irrigation disruption at capsule formation stage, irrigation disruption at grain filling stage was considered. Cultivation operations were conducted on May 20th, 2016. Each experimental plot included 4 cultivation rows with 4 meters in length and 50cm distances in row and distance between plans in each row was 8 cm. the seeds were planted at 2-3c depth through dry soil with density of 25 plants per m2. According to the soil test, triple superphosphate fertilizer (150 kg.ha-1) before planting and fertilizer of urea (200 kg ha-1) were used in two stages before planting and during flowering in experimental plots while Potassium Fertilizer was not used due to high amount of potassium in soil. The Barvar-2 phosphate biofertilizer used for this experiment was supplied by Green Biotechnology Company in Iran; Phosphate- EBarvar2 consisted of two kinds of phosphate solubilizing bacteria, Pseudomonas putida (strain p13) and Bacillus lentus (strain p5). Pseudomonas putida by producing of organic acids caused released of the phosphates from inorganic compounds whereas Bacillus lentus by producing of phosphatase enzyme causes release of the phosphate from organic compounds (Raissi et al ., 2012).

In order to apply Barvar-2 phosphate biofertilizer, first, 100 g.ha-1 of this biofertilizer was solved in a 10-liter water then the sesame seeds were placed in water containers with fertilizer solution for 10 minutes before cultivation and then were planted. Irrigation was carried out at intervals every 10 days and weeds were removed manually during the growing season.

Table 1. Physical and chemical characteristics of soil

pH	K, (ppm)	P, (ppm)	N, (%)	OC, (%)	Sand, (%)	Clay, (%)	Silt, (%)	Soil texture	EC (ds/m)
8.13	415.8	4.8	0.06	0.55	34	19	47	loam	0.82

In this experiment, plant height, number of branches per plant, 1000 seed weight, number of capsules per plant, seed number per capsule, seed oil percent and seed yield were measured. To determine the traits of plant height, number of branches per plant, number of capsules per plant and number of seeds in capsules, eight plants in each experimental plot were selected randomly and their average was recorded as the mentioned traits. Yield seed was calculated at a level equal to 2m2 after drying and reaching the seeds moisture to 13-14 percent. To determine the percent of seed oil, the Soxhlet machine was used. Then data were analyzed by MSTATC software and means compared with Duncan's Multiple Range Test at 5% probability level.

Results and discussion

Plant height

Plant height was affected by irrigation disruption at 95% probability (Table 2). The highest plant height was observed in the irrigation disruption and the lowest plant height was observed at irrigation disruption in 10 leaf stage (Table 3). irrigation disruption at this stage prevents vegetative growth and, as a result, the plant height has decreased. Due to decreasing Turgor pressure of the stem cells under drought stress condition which is increasing in length, and on the other hand, the production of materials from photosynthesis decreases. Therefore, the length of stem internodes and as a result the height of plant decrease under drought conditions (Rabbani and Imam, 2011). Decreasing plant height with irrigation disruption can result in photosynthesis disruptions due to lack of soil moisture and reduction of photosynthetic material production to provide growing parts of the plant and eventually lack of access to genetic potential in terms of height (Ghexvi et al., 2004). Cell growth in plant is an activity that is very sensitive to water scarcity. Reducing the water potential of mercantile tissues often results in a decrease in compressive potential to a level that is less than the amount required for cell growth, which reduces the protein synthesis and degrades the growth of the cell (Piro et al., 2009). Studies by Mehrabi and Ehsanzadeh (2010) on sesame plant showed that plant height decreased with decreasing irrigation water before flowering stage.

Number of branches per plant

The effect of Barvar-2 phosphate biofertilizer on number of branches per plant was significant at 95% probability level (Table 2). The highest number of branches per plant was observed in bio phosphorus treatment (Table 3). Bio-fertilizer seems to enhance plant growth by increasing free phosphorus of soil, and more photosynthetic materials are produced in the plant, and the growth of growing sprouts are stimulated and number of branches per plant have increased. Lopez (2003) stated that under conditions of phosphorus deficiency, the increased activity of hormones such as ethylene inhibits the growth and development of plant air organs; and in the case of phosphorus deficiency, the activity of hormones such as cytokinin, which plays a vital role in the division and development of cells in meristem areas, is also reduced, But under phosphorus conditions, the activity of these hormones increases and enhances the growth of plant organs. In order to investigate the effect of phosphorus and nitrogen fertilizers on quantitative and qualitative traits of brassica plant, Karami et al. (2011) concluded that the treatments had a significant effect on plant height, number of stems, yield of flowering shoots, percentage and yield of Viper's bugloss. The effect of irrigation disruption on number of branches per plant was significant at the probability level of 99% (Table 2). The highest number of branches per plant was observed at state under irrigation disruption and the lowest number of branches per plant was observed at state under irrigation disruption at 10 leaf stage (Table 3). Drought stress, due to leaf photosynthesis, decreases the production of plant material and growth, and the number of branches in the plant decreases. Ayin (2013) stated that irrigation removal at vegetative growth stage significantly reduced the number of sesame sub branch.

Table 2. Analysis of variance of irrigation disruption and Barvar-2 phosphate biofertilizer on different traits of sesame

S.O.V	df	Means of Squares						
		Plant height	number of branches in a plant	Number of capsules per plant	Number of seeds per capsule	the weight of 1000 seeds	seed yield	Oil percent
Replications	2	28.052	1.133	14.398	13.29	0.091	297577.017	0.53
Barvar-2 phosphate biofertilizer	1	14.324	1.71*	101.6*	143.5*	0.06	364698.2*	163.7*
Main error	2	95.921	0.063	2.151	3.65	0.01	20568.271	6.623
irrigation disruption	4	197.47*	2.6**	200.5**	49.8**	0.30**	1526923.42**	8.378**
B× I	4	2.293	0.203	3.342	4.271	0.005	68813.9	0.499
Minor error	16	49.163	0.39	12.937	2.835	0.018	81754.191	1.125
CV (%)		6.4	10.86	10.73	4.86	4.42	17.70	2.53

*, ** significant at 95% and 99%, respectively

Number of capsules per plant

The effect of Barvar-2 phosphate biofertilizer on the number of capsules per plant was significant (Table 2). The highest number of capsules per plant belonged to biological phosphorus treatment and the lowest number of capsules per plant belonged to control treatment (no fertilizer application) (Table 3). Dania et al. (2013) also stated in a trial that there is a positive and significant correlation between the number of capsules and the number of branches per plant. Nasrollahzadeh Asl (2017), in studying the effect of Bio-fertilizer (Phosphate Barvar2) and nitroxin on sesame, said that Bio-fertilizer (Phosphate Barvar2) significantly increased the number of capsules per plant. Also, in a research on replacing bio fertilizer with chemical fertilizer by al-Kermani et al (2007) on peanuts, it was found that increasing the number of nuts in plants was related to treatments that received 25% chemical fertilizer and 75% bio-fertilizer. The effect of irrigation disruption on the number of capsules per plant was significant at the probability level of 1% (Table 2). The highest number of capsules was observed in normal irrigation and the lowest number of capsules per plant was observed in irrigation disruption at flowering stage of sesame (Table 3). Flowering stage is the most sensitive plant growth period to drought stress (Imam and Ranjbar, 2001). Farahbakhsh (2014) also claimed that drought stress at flowering stage caused the greatest decrease in the number of capsules per sesame plant. Also, Dyota et al. (2000) showed that with drought stress, the number of capsules per sesame plant decreases. Gupta and Coopera (1984) reported the number of capsules per plant as the most important component of sesame seed yield.

Number of seeds per capsule

The effect of Barvar-2 phosphate biofertilizer on seed number per capsule was significant at 95% probability level (Table 2). The highest number of seeds per capsule was observed in Bio-fertilizer (Phosphate Barvar2) treatment, and the lowest number of nuts per plant was also allocated to control treatment (no fertilizer application) (Table 3). Phosphorus is one of the effective factors on the improvement of reproductive characteristics of the plant and increases the number of flowers, seeds and fruits

(Cook, 2005; Alkholi et al., 2005). Yousefpour and Eidavi (2013) stated in a trial that Barvar-2 phosphate biofertilizer significantly increased the number of seeds per sunflower. The effect of irrigation disruption on the number of seeds per capsule was significant at the probability level of 99% (Table 2). The highest number of seeds per capsule in normal irrigation and irrigation disruption in V10 stages and the lowest seed number in the sesame plant capsule also belonged to the irrigation disruption in the capsulation stage (Table 3). Jane et al. (2010) stated in a trial that irrigation disruption at critical stages of capsulation and seed filling reduced the number of seeds per capsule more than other treatments.

Table 3. Comparison of mean of different levels of irrigation disruption and Barvar-2 phosphate biofertilizer on different traits of sesame

Experimental factor		Plant height (cm)	Number of branches per plant	Number of capsules per plant	Number of seeds per capsule	1000 seed Weight (g)	seed yield ($kg.ha^{-1}$)	Oil percent (%)
Barvar-2 phosphate biofertilizer 2)	Control (no fertilizer)	108.82	5.41 b	31.69 b	32.45b	2.98	1505.52 b	39.56 b
	Bio-fertilizer	110.21	6.08 a	35.37 a	36.83 a	3.06	1726.03 a	44.23 a
irrigation disruption	Normal Irrigation	116.3 a	6.52 a	41.76 a	37.74 a	3.23 a	1985 a	43.53 a
	irrigation disruption at 10 leaf stage	100.8 b	4.78 c	36.78 b	37.09 a	3.22 a	1825 ab	42.5 ab
	irrigation disruption at flowering stage	108.6 ab	5.57 b	27.39 d	34.26 b	3.03 b	1214 c	41.74 b
	irrigation disruption at capsule formation stage	109.4 ab	5.73 ab	29.53 cd	30.64 c	2.93b	1496 bc	41.27 b
	irrigation disruption at the seed filling stage	112.5 a	6.14 ab	32.2 c	33.45 b	2.69 c	1558 bc	40.43 c

Dissiminant letters in each column indicate the significant defferences at 95 level

1000 seed weight

The effect of Barvar-2 phosphate biofertilizer on 1000 seed weight was not significant (Table 2). It seems that 1000-grain weight is more affected by the genotype, so fertilization could not significantly increase the weight of 1000 seeds. Fazeli et al. (2012) stated in a trial that the weight of 1000 seeds of sesame seeds was most affected by genetic control. The effect of irrigation disruption on 1000 grain weight was significant at 1% probability level (Table 2). The highest 1000-grain weight was observed in normal irrigation, which did not show significant differences with irrigation disruption at 10 leaf stage. The lowest 1000-grain weight was obtained in irrigation disruption at the seed filling stage (Table 3). As the seed is growing in the filling stage, any drought stress at this stage can reduce photosynthesis and less photosynthetic material is transferred to the seeds, which reduces the weight of the seeds. Drought stress can greatly reduce the amount of crop production by affecting the degree of opening of the apertures, reducing the activity of the Calvin cycle enzymes (Pesarakly, 2001), which directly reduces the weight of a thousand seeds (Salispour et al., 2006). Ayin (2013) showed that drought stress in seed filling stage had the greatest damage per 1000 seed weight. Nouriani (2014) showed that drought stress in seed filling stage caused reduction of 1000 grain weight in mushroom due to reduction of effective grain filling period and reduction of synthesis and transfer of photosynthetic material to growing seeds.

Seed yield

The effect of Barvar-2 phosphate biofertilizer on seed yield was significant at 99% probability level (Table 2). The highest seed yield was observed in Barvar-2 phosphate biofertilizer treatment and the lowest seed yield was observed in control treatment (no fertilizer application) (Table 3). Bio-fertilizer (Phosphate Barvar2) increased the grain yield by helping dissolve phosphorus compounds in the soil and facilitating its absorption by the plant. Jahan et al. (2013) stated that the use of Biofossor biofertilizers, a set of phosphate and biosulfur soluble bacteria in sesame plant, significantly increased the grain yield and biological yield, and the components of yield, compared to the control treatment (no use Fertilizer). Yassari et al. (2008) also stated in a trial that phosphate-soluble bacteria, in addition to dissolving insoluble phosphates, increased yield and growth of sunflower seeds by stimulated growth hormones such as indole acetic acid, gibberellins, and cytokinins. Mittal et al. (2007) stated in their study that phosphate-soluble microorganisms, through the production of auxin hormone, affect the growth and development of chickpea and increase their growth indices. Nasrollahzadeh Asl (2017) reported that the use of phosphorous biofertilizer and different amounts of phosphorus fertilizer significantly increased sesame seed yield. The effect of irrigation disruption on grain yield was significant at 1% probability level (Table 2). The highest seed yield was observed in normal irrigation and the lowest seed yield in irrigation disruption at flowering stage (Table 3). Since the lowest number of capsules per plant was observed at irrigation disruption stage at flowering stage, and there was a significant correlation between grain yield and number of capsules per plant, thus the lowest grain yield was observed in irrigation disruption at flowering stage. Gupta and Coopera (1984) reported the number of capsules per plant as the most important component of sesame seed yield. Also, Ahmadi and Bahrani (2009) reported that the number of capsules per plant was an effective part of the sesame plant and had a significant positive correlation with other components of yield. Hasani et al. (2012) during the experiment, the lowest yield of sesame seeds was observed at the irrigation disruption stage at flowering stage. Some reports suggest that the most sensitive stages of water stress in sesame plants are the reproductive stage (Gattiir et al., 2001). During the experiment, drought stress at flowering stage caused the highest grain yield reduction (Farahbakhsh and Farahbakhsh, 2014). Jain et al. (2010) showed that drought stress at flowering stage had a significant effect on plant height, capsule size, seed number per capsule and grain yield in studying the effect of drought stress on growth and characteristics related to yield in sesame. Sadeghipour (2008) studied the effect of irrigation disruption in different stages of growth on yield and components of mung bean and concluded that drought stress at reproductive stage, especially flowering stage and pod formation, affected grain yield compared to stress in other stages of growth. Therefore, irrigation at flowering stage and formation of pods to achieve the maximum grain yield is essential.

Seed oil percent

The effect of Barvar-2 phosphate biofertilizer on seed oil percent was significant at 5% probability level (Table 2). The highest percent of seed oil was observed in Barvar-2 phosphate biofertilizer treatment and the lowest seed oil content belonged to control treatment (no fertilizer application) (Table 3). Phosphorus fertilizer seems to increase plant growth by increasing soil fertility, and as a result, the plant's photosynthesis level has increased, and more photosynthetic material has been produced and, consequently, the percent of oil has gone up. Boss (2003) stated in a test that phosphorus in Rapeseed planting had a significant effect on the amount of seed oil, so that the severe deficiency of phosphorus reduced the amount of oil from 33% to 23%. Ojaghlu et al. (2007) stated that the use of Bio-fertilizer (Phosphate Barvar2) can be effective in increasing the percentage of seed oil of safflower with a separate mechanism, provided that it is used in combination with chemical fertilizer at half the recommended amount. The effect of irrigation disruption on seed oil content of sesame seeds was significant at 1% probability level (Table 2). The highest percentage of seed oil was obtained in normal irrigation and the lowest percentage of seed oil was obtained in irrigation disruption at the filling stage (Table 3). Naderi Dabbaghashahi et al. (2005) showed that drought stress reduced the yield of summer safflower oil in Isfahan region. Sharifi et al. (2008) showed that the highest yield and percentage of sunflower seeds oil was obtained from irrigation disruption treatments. Gholinejad et al. (2012) stated in an experiment on sunflower that severe drought stress reduced the percentage of seed oil compared to optimal irrigation due to the fact that carbohydrates first accumulate and then turn to oil and protein or any substance, whereby the longer it will become, so the longer the grain lasts, the higher the oil content.

Conclusion

By using Barvar-2 phosphate biofertilizer, yield and seed oil content increased. Flowering stage is also the most sensitive stage in drought stress in sesame seeds, so that grain yield decreased by about 35% under irrigation disruption. However, with irrigation disruption, in the 10-leaf stage, grain yield was not significantly reduced compared to full irrigation, which can be saved by water removal at this stage of development, especially in low water areas.

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