Journal of Medicinal Plants and By-products (2017) 1: 17-25

Original Article

Biofertilizers and Drought Stress Effects on Yield and Yield Components of Fennel (*Foeniculum vulgare* Mill.)

Khosro Azizi *

Lorestan University, College of Agriculture, Department of Agronomy, Khorramabad, Iran

Article History: Received: 05 May 2016 /Accepted in revised form: 01 July 2017

Abstract

Effects of biofertilizers and stacosorb polymer* on yield and yield components of fennel (*Foeniculum vulgare* Mill.) under drought stress were evaluated using a split-factorial experiment based on a randomized complete block design (RCBD) with three replications at the agricultural research farm of Lorestan University, Khorramabad, Iran in 2013. The factors included drought condition (stressed and non-stressed) in the main plots, biofertilizer (nitroxin and barvar-2 phosphate) and stacosorb polymer [control and non-control] in the sub-plots. Results showed use of the biofertilizers had positive effects on the umbel number per plant, seed number per umbel, seed number per plant, harvest index, total dry matter, seed yield, plant height, and essential oil yield and percentage. The use of stacosorb had a significant positive effect on the plant height and seed number per plant under drought condition. The highest 1000-seed weight (4.82 g) was recorded in treatment with no fertilizer in the non-stressed plots. The highest total dry matter (192.7 g/m^2) and seed yield (56.57 g/m^2) were obtained from treatment with nitroxin in the non-stressed plots. The highest harvest index (45.24%) was recorded in treatment with the barvar-2 phosphate biofertilizer in the non-stressed plots. In conclusion, the biofertilizers affected significantly on some important traits of fennel. Also stacosorb polymer could counteract the unfavorable consequences of drought stress.

Keywords: Biofertilizer, Drought stress, Fennel, Oil, Yield

*Highly absorbent polymers are hydrophilic gels which absorb water and release it gradually when the soil is dry so that the soil becomes wet for a long time

Introduction

Excessive consumption of chemical fertilizers, pesticides, and fungicides in industrial agriculture has led to many environmental hazards, such as soil and water contamination, crop quality degradation, and soil biological imbalance, which cause irrevocable damages to the ecosystems [1,2]. Bacteria that live in Rhizosphere enhance root growth by nominating biological materials, such as auxin and gibberellins, and cause an increase in nutrient uptake from soil and all these conditions influence plant vegetative and reproductive growth.
Abo-baker and Mostafa [3] reported positive effects of consumption of biological fertilizers on Hibiscus tea plant *(Hibiscus sabdariffa* L.). Barvar-2 is an organic phosphorus fertilizer that contains two species of phosphate solubilizing bacteria (PSB), namely, *Bacillus lentus* and *Pesudomonas potida*, which solubilize soil's insoluble phosphorus and make it available for plants by secretion of organic and phosphatase acids, respectively. Also, Nitroxin is a biological fertilizer that contains many nitrogen fixation bacterias [4]. The sustainability agriculture basement utilization of biotic fertilizers is one solution to reduce chemical inputs. Thus, sustainable farming system led to reduced environmental perils and conservation of ecological aspects [5].
Super absorbent polymer plays an important role in enhancement of absorption capacity and retention

*Corresponding author: Lorestan University, College of Agriculture, Department of Agronomy, Khorramabad, Iran
Email Address: azizi_kh44@yahoo.com

of water in soil, fighting against water shortage, and decreasing harmful effects of drought stress. Highly absorbent polymers are hydrophilic gels which absorb water and release it gradually when the soil is dry so that the soil becomes wet for a long time. Super absorbent polymers may have great potential in restoration and reclamation of soil and storage of available water for plant growth and production. Super absorbent polymer works by absorbing and storing water and nutrients in a gel form and hydrating and dehydrating as the demand for moisture fluctuates [6].

The recent global trend in production of medicinal plants is in favor of sustainable agriculture. One of the efficient practices of sustainable agriculture is the application of biological fertilizers for quantitative and qualitative yield improvement in medicinal plants, such as fennel, which is of great significance in food, pharmaceutical, and cosmetic industry. Fennel (*Foeniculum vulgare* Mill.) is an umbelliferous plant [7]. It is an herbaceous and perennial plant which is indigenous to the Mediterranean region and Southern Europe. The valuable parts include its mature fruits, flowers, and dry roots and its seeds are often used in the extraction essential oil [8]. Fennel essential oil contains more than 30 different terpene or terpenoid compounds. Anethole is the major component in the essence of Sweet fennel (*F. vulgare*) that has a major role on its essence quality [9]. However, the most important compound of fennel is Anethole and is widely used in perfumery and pharmaceutical industry [10]. In discussing about the importance of fennel as a medicinal herb on one hand and the dry and semi-dry climate of Iran on the other hand, this research was conducted to study the interaction of nitroxin and barvar-2 phosphate biofertilizers and stacosorb polymers on yield and yield components of fennel under moderate drought stress.

Material and Methods

This study was conducted on the agricultural research farm of Lorestan University (Khorramabad, Iran) in the growing season of 2013. The experimental site was located at a latitude 33°26′ N, a longitude 45°17′ E, and an altitude of 1210 m with a semi-arid climate, mean annual precipitation of 462.8 mm, mean annual evaporation of 1842.52 mm, and mean annual temperature of 16.6 °C. A soil sample was randomly collected from the depth of 0 to 30 cm to determine the chemical and physical properties of the soil (Table 1). The experiment was a split-factorial study arranged in a randomized complete block design (RCBD) with three replications. The studied factors included two levels of the drought condition (stressed (W_1)[1] and non-stressed (W_0)) [2] in the main plots and a combination of two levels of the nitroxin biofertilizer[3] (applied (N_1) and not applied (N_0)), two levels of the barvar-2 phosphate biofertilizer (applied (B_1) and not applied (B_0)), and two levels of the stacosorb polymer[4] (applied (S_1) and not applied (S_0)) in the subplots.

1. W_1: Stressed drought. The treatment of the drought stress, the degree of humidity of the soil was about 60-70 percent of the capacity of the field.

2. W_0: Non-stressed drought. The treatment of the non-stress drought, the degree of humidity of the soil was in the 100 percent capacity of the field.

3. The biologic fertilizer of nitroxine contains bacteria which stabilizes azotes of the Azotobacter and Azospirillum types and dissolves Pseudomonas phosphate, which is used in a liquid form [11].

4. Highly absorbent polymers are hydrophilic gels which absorb water and release it gradually when the soil is dry so that the soil becomes wet for a long time.

There was a 4 m space between the main plots to avoid interference between stressed and non-stressed treatments. The subplots were made up of 5 sowing lines with a 2 cm space between the seeds in the lines and a 25 cm space between the lines. Seed inoculation method was used for the application of the nitroxin and barvar-2 phosphate biofertilizers. One milliliter of nitoxin was used for 3.6 g of fennel seeds in each subplot. Concerning the recommended amount of 100 g/ha for the barvar-2 phosphate biofertilizer, 45 mg of the barvar-2 phosphate biofertilizer were mixed with 3.6 g of the fennel seeds in each 4.5 m^2 subplot. Furthermore, 36 g of the superphosphate and urate chemical fertilizers were used as the base fertilizer. 21.6 g of the stacosorb polymer were placed at the depth of 4 to 5 cm in each sowing line. The stacosorb polymer was covered using a layer of soil and then the seeds were planted. The first irrigation was done immediately after sowing and the weeds were collected by hand. Irrigation was done at an interval of 7 days during the growth period. Drought stress was imposed from the beginning to the end of the flowering period.

The treatment of the non-stress drought, the degree of humidity of the soil was in the 100 percent capacity of the field. The treatment of the drought stress, the degree of humidity of the soil was about 60-70 percent of the capacity of the field. To determine the amount of the humidity weight of the soil, the following formula was used:

$$\frac{\text{Weight of Wet Soil} - \text{Weight of Dry Soil}}{\text{Weight of Dry Soil}} \times 100$$

A tensiometer device was used to determine the degree of the humidity of the soil. A frequent and regular sampling was made of the experimental plots to determine the amount of the humidity weight of the soil. In this experiment, the degree of humidity weight of the soil was 22 % in the non-tension plots while this amount was about 13.2 to 15-4 % in the plots under the drought tension. Concerning the climatic conditions, the minimum soil moisture was reached after 14 days when the tensiometer showed -33 kpa water pressure.

The morphological characteristics were measured after the end of the tension. Plants were harvested manually on October 20, 2012. At the harvest stage, 10 plants were randomly collected from an area of 1 m^2 of the three middle rows of each subplot to measure plant height, number of umbel per plant, number of seeds per umbel, and number of seeds per plant. Five samples of 1000 seeds were randomly collected from each subplot and the shadow was dried to determine 1000-seed weight. After the elimination of the border effect, 2 m^2 of each subplot was also harvested to measure biological and seed yields. The seed essential oil content was measured by hydro-distillation (distillation with water) of a sample of 50 g pulverized seeds from each subplot using a Clevenger apparatus for 4 h.

The obtained data were subjected to statistical analysis using the Microsoft Office Excel, MSTAT-C and SPSS statistical software packages. Means were compared using Duncan's multiple range test. SPSS statistical software was also used to explore the correlation among the studied characteristics.

Results

Plant Height

Analysis of variance showed that the double interaction of nitroxin and barvar-2 phosphate biofertilizers significantly affected the plant height in fennel at 5% probability level and other factors had no significant effects (Table 2). Means of the fourfold interaction showed that the highest plant height (55.43 cm) was associated with the application the barvar-2 phosphate biofertilizer and stacosorb polymer and non-application of the nitroxin biofertilizer under stressed condition (Table 5). The positive effect of the stacosorb polymer on counteracting the unfavorable consequences of drought stress in olive is proven [12]. Mahfouz and Sharaf-Eldin [13] reported that the application of organic fertilizers significantly increased the plant height in fennel. Water deficiency can decrease cellular turgescence and lead to a decrease of cellular growth especially in the stem and leaves. Some studies reported that drought stress decreased the total dry matter yield in *Rosmarinus officinalis* L. and *Thymus transcaspicus* Klokov [14].

Table 1 Results of physical-chemical analysis of soil of the research farm.

Factor Rate Unit	Factor Rate Unit	Factor Rate Unit
Nitrogen	98	(%)
OC	1.03	(%)
P	9.4	(PPM)
K	410	(PPM)
Mg	2.9	(PPM)
Ca	3.3	(PPM)
EC	0.47	(ds/m)
pH	8.5	
Loam	44	(%)
Clay	32	(%)
Sand	24	(%)
Soil texture	loam-clay	

Seed Number and Yield

The studied treatments significantly affected the number of umbels per plant (Table 4). Means of the fourfold interaction showed that the highest number of umbels per plant (39.77) was associated with the application of the nitroxin biofertilizer under the non-stressed condition (Table 5). Due to the increase of the effect of inoculation with the root of this plant, Nitragin, and the effect of these changes on the length and number of branches and sub-root, fennel seed germination was affected by seed treatment with Nitragin rose sharply. Concerning the germination of fennel seeds, it seems that the relative improvement over the use of seedlings in the green timely Nitragin and uniform seed is effective under field conditions [15]. Mahfouz and Sharaf-Eldin [13] also reported that the number of umbels per plant significantly increased fennel by the application of the biofertilizer. Regarding the effect of the irrigation regimen on the anise medicinal plant, it was reported that the number of umbels per plant and the number of umbellule per umbel would significantly decreased by reducing irrigation [16].The number of umbels per plant highly depends on the factors contributing to rapid plant growth, especially, appropriate nutrients and sufficient soil moisture.

The studied treatments significantly affected the number of seeds per umbel (Table 2). Means of the fourfold interaction showed that the highest number of seeds per umbel (16.13) was associated with the application of the nitroxin biofertilizer, barvar-2 phosphate biofertilizer and stacosorb polymer under stressed condition (Table 5). It is believed that biological fertilizers which contain growth stimulant bacteria contributed to the increase of the number of seeds per umbel in fennel and the stacosorb polymer counteracted the unfavorable consequences of the drought stress.

Bio-fertilizers are widely applied in crop production and they are proper substitutions for chemical fertilizers (. The studied treatments significantly affected the number of seeds per plant (Table 2). Means of the fourfold interaction showed that the highest number of seed per plant (404) was associated with the interaction of the application of nitroxin and barvar-2 phosphate biofertilizers and non-application of the stacosorb polymer under non-stressed conditions (Table 5). The obtained results were also in agreement with another study on green cumin which showed that an increase in irrigation times would increase the number of seeds per plant through the positive effect of irrigation at the flowering period on the number of seeds per umbel [17]. Since the number of seeds per plant is obtained by multiplying the number of umbels per plant and seeds per umbel, an increase in the number of seeds per plant can also be attributed to nutrient availability through the consumption of nitroxin and barvar-2 phosphate biofertilizers under non-stressed condition.

The studied treatments significantly affected the 1000-seed weight (Table 4). Means of the fourfold interaction showed that the highest 1000-seed weight (4.82 g) was associated with the control treatment, that is, non-application of the nitroxin biofertilizer, barvar-2 phosphate biofertilizer, and stacosorb polymer under non-stressed conditions (Table 5). *Azotobacter* can affect plant growth directly, either by the nitrogen it fixes [18,19].

Total Dry Matter (Biological Yield) and Harvest Index

Analysis of variance showed that the interaction of the nitroxin biofertilizer application under drought stress condition significantly affected the total dry matter at 5% probability level. Other factors had no significant effect on the total dry matter (Table 3). Means of the fourfold interaction showed that the highest total dry matter (192.7 g/m^2) was associated with the application of the nitroxin biofertilizer and non-application of the barvar-2 phosphate biofertilizer and stacosorb polymer under non-stressed conditions (Table 5). Biological fertilizers are widely applied in crop production and they are proper substitutions for chemical fertilizers. The application of biological fertilizer significantly improved the yield and yield components in cumin [20]. The use of biological nitrogen fixation by living nitrogen fixers will help minimize the use of chemical nitrogen fertilizer and improve plant growth to decrease the production cost and environmental risk [21].

The studied treatments significantly affected seed yield (Table 2). Means of the fourfold interaction showed that the highest seed yield (56.57 g/m^2) was associated with the application of the nitroxin biofertilizer and non-application of the barvar-2 phosphate biofertilizer and stacosorb polymer under non-stressed conditions (Table 5). The obtained results were in agreement with Hosein Talaei *et al*. [20] who reported that biological fertilizers are widely applied in crop production and they are proper substitutions for chemical fertilizers. The application of biological fertilizer significantly improved the quality and quantity features in cumin. Khalili-Mahalleh *et al*. [22] reported that with drought stress in forage crops, ash percent decreased significantly. The ash content is a mark of all minerals except I 1 and Cl 1, because these elements sublimate by burning in electrical furnace. Each deficiency of minerals in food of herbivorous could lead to some diseases, such as milk fever, etc. Khadem *et al*. [23] reported that protein and ash content increased with superabsorbent application. In order to study the coriander responses to irrigation, Surendra *et al*. [24] showed that a three-time irrigation schedule at the stem growth, flowering, and seed filling periods increased seed yield when compared with a one- or two-time irrigation schedule. This is also in agreement with the obtained results of the present research.

The studied treatments significantly affected the fennel harvest index (Table 4). Means of the fourfold interaction showed that the highest harvest index (0.45%) was associated with the application of the barvar-2 phosphate biofertilizer and non-application of the nitroxin biofertilizer and stacosorb polymer under non-stressed conditions (Table 5).

Essential Oil

The studied treatments significantly affected the essential oil percentage in fennel (Table 2). Means of the fourfold interaction showed that the highest essential oil percentage (5.383%) was associated with the application of the nitroxin biofertilizer and stacosorb polymer and non-application of the barvar-2 phosphate biofertilizer under non-stressed conditions (Table 5). It was reported that the application of the biofertilizers increased the essential oil percentage in fennel [13]. A study on *Matricaria chamomilla* L., *Artemisia absinthium* L., and *Lavandula spica* L. revealed that although irrigation increased essential oil, their relative value (phytochemical quality) was higher in drought stress condition [25].

The studied treatments significantly affected essential oil yield in fennel (Table 2). Means of the fourfold interaction showed that the highest essential oil yield (1.301 mg/m^2) was associated with the application of the nitroxin biofertilizer, barvar-2 phosphate biofertilizer, and stacosorb polymer under non-stressed conditions (Table 5). The increase in biological yield and essential oil yield is attributed to complete irrigation during the growth period [26]. This is in agreement with the results obtained in the present study. Zehtab-Salmasi *et al*. [16] reported that the water deficiency decreased essential oil yield in Anise. It is supposed that, due to the increase of intracellular oxidation under drought stress or the water deficiency, the production of active ingredients is decreased.

Table 2 Analysis of variance for the effect of nitroxin biofertilizer, barvar-2 phosphate biofertilizer, and the stacosorb polymer under drought stress condition on the studied characteristics of fennel.

		Mean squares									
Source of variation	Df	Plant height	Umbel/plant	Seed/umbel	Seed/plant	1000-seed weight	Total dry matter	Seed yield	Harvest index	Essential oil percentage	Essential oil yield
Replication	2	0.327^{ns}	37.729^{ns}	0.745^{ns}	4191.510^{ns}	0.108^{ns}	584.927^{ns}	2.162^{ns}	0.365^{ns}	0.725^{ns}	0.052^{ns}
A	1	44.294^{ns}	296.013^{**}	0.403^{ns}	16236.164^{ns}	2.906^{*}	2002.083^{ns}	102.690^{ns}	16.055^{**}	29.188^{**}	1.091^{*}
Error 1	2	132.673	2.138^{1}	0.515	3001.632	0.097^{1}	356.644^{1}	19.301	0.040^{1}	0.202	0.012
B	1	0.012^{ns}	64.867^{**}	0.801^{ns}	148.403^{ns}	0.160^{ns}	2563.763^{ns}	7.790^{ns}	3.532^{**}	0.105^{ns}	0.020^{ns}
AB	1	1.699^{ns}	0.301^{ns}	0.441^{ns}	20.280^{ns}	0.036^{ns}	39.241^{ns}	7.922^{ns}	0.986^{**}	1.932^{**}	0.085^{**}
C	1	13.964^{ns}	0.607^{ns}	9.901^{**}	10.268^{ns}	0.266^{ns}	1523.253^{ns}	1.577^{ns}	7.473^{**}	0.172^{ns}	0.011^{ns}
AC	1	2.453^{ns}	3.308^{ns}	0.301^{ns}	1716.020^{ns}	1.370^{**}	5750.940^{*}	42.375^{*}	0.145^{ns}	2.104^{**}	0.000^{ns}
BC	1	120.682	7.053^{ns}	38.163^{**}	9146.641^{ns}	1.446^{**}	845.041^{ns}	79.825^{**}	18.976^{**}	0.032^{ns}	0.168^{**}
ABC	1	13.771^{ns}	7.636^{ns}	6.163^{**}	1371.741^{ns}	0.030^{ns}	784.083^{ns}	0.285^{ns}	3.456^{**}	0.284^{ns}	0.008^{ns}
D	1	4.447^{ns}	0.441^{ns}	0.333^{ns}	1822.867^{ns}	0.030^{ns}	40.333^{ns}	37.985^{*}	13.782^{**}	7.138^{**}	0.633^{**}
DA	1	32.062^{ns}	10.641^{ns}	1.763^{ns}	17442.190^{*}	0.076^{ns}	117.187^{ns}	21.200^{ns}	0.484^{**}	0.809^{*}	0.056^{*}
DB	1	0.153^{ns}	62.563^{**}	14.301^{**}	612.041^{ns}	0.000^{ns}	763.207^{ns}	0.500^{ns}	4.839^{**}	0.146^{ns}	0.000^{ns}
ABD	1	18.364^{ns}	19.253^{ns}	0.441^{ns}	0.187^{ns}	0.068^{ns}	733.203^{ns}	33.500^{*}	4.775^{**}	0.819^{*}	0.065^{*}
CD	1	5.985^{ns}	0.163^{ns}	8.841^{**}	6156.269^{ns}	0.000^{ns}	59.408^{ns}	0.035^{ns}	0.682^{**}	0.793^{*}	0.024^{ns}
ACD	1	42.507^{ns}	28.213^{*}	9.901^{**}	9792.654^{ns}	0.067^{ns}	116.563^{ns}	0.775^{ns}	3.641^{**}	0.050^{ns}	0.000^{ns}
BCD	1	0.309^{ns}	37.808^{*}	6.750^{**}	1075.413^{ns}	0.007^{ns}	1252.564^{ns}	0.002^{ns}	0.168^{ns}	1.624^{*}	0.043^{*}
ABCD	1	1.323^{ns}	19.001^{ns}	0.013^{ns}	20024.673^{*}	0.061^{ns}	3303.401^{ns}	29.610^{*}	0.323^{ns}	0.001^{ns}	0.021^{ns}
Error 2	28	16.882	5.537^{1}	0.425	2954.778	0.149^{1}	977.251^{1}	5.635	0.087^{1}	0.146	0.009
C V (%)	-	7.94	7.05	4.95	17.41	9.08	19.64	10.75	1.74	10.22	11.58

** Significant at 1%, * significant at 5%, and ^{ns} not significant.

Table 3 Analysis of variance after removing the correlation of block and sub-factor from sub-plot error.

		Mean squares			
Source of variation	Df	Umbel/plant	1000-seed weight	Total dry matter	Harvest index
Replication	2	37.729^{ns}	0.108^{ns}	584.927^{ns}	0.365^{ns}
A	1	296.013**	2.906*	2002.083^{ns}	16.055**
Error 1	2	2.138^{1}	0.097^{1}	356.644	0.040^{1}
B	1	64.867**	0.160^{ns}	2563.763^{ns}	3.532**
AB	1	0.301^{ns}	0.036^{ns}	39.241^{ns}	0.986**
C	1	0.607^{ns}	0.266^{ns}	1523.253^{ns}	7.473**
AC	1	3.308^{ns}	1.370**	5750.940*	0.145^{ns}
BC	1	7.053^{ns}	1.446**	845.041^{ns}	18.976**
ABC	1	7.636^{ns}	0.030^{ns}	784.083^{ns}	3.456**
D	1	0.441^{ns}	0.030^{ns}	40.333^{ns}	13.782**
DA	1	10.641^{ns}	0.076^{ns}	117.187^{ns}	0.484**
DB	1	62.563**	0.000^{ns}	763.207^{ns}	4.839**
ABD	1	19.253^{ns}	0.068^{ns}	733.203^{ns}	4.775**
CD	1	0.163^{ns}	0.000^{ns}	59.408^{ns}	0.682**
ACD	1	28.213*	0.067^{ns}	116.563^{ns}	3.641**
BCD	1	37.808*	0.007^{ns}	1252.564^{ns}	0.168^{ns}
ABCD	1	19.001^{ns}	0.061^{ns}	3303.401^{ns}	0.323^{ns}
Error 2	14	5.842^{1}	0.12^{1}	308.415	0.092^{1}
C V (%)	-	7.05	9.08	19.64	1.74

** Significant at 1%, * significant at 5%, and ^{ns} not significant.

Table 4 Secondary analysis of variance (analysis of variance by factorial method).

		Mean squares		
Source of variation	Df	Umbel/plant	1000-seed weight	Harvest index
Replication	2	37.729**	0.108^{ns}	0.365*
A	1	296.013**	2.906**	16.055**
B	1	64.867**	0.160^{ns}	3.532**
AB	1	0.301^{ns}	0.036^{ns}	0.986**
C	1	0.607^{ns}	0.266^{ns}	7.473**
AC	1	3.308^{ns}	1.370**	0.145^{ns}
BC	1	7.053^{ns}	1.446**	18.976**
ABC	1	7.363^{ns}	0.030^{ns}	3.456**
D	1	0.441^{ns}	0.030^{ns}	13.782**
DA	1	10.641^{ns}	0.076^{ns}	0.848**
DB	1	62.563**	0.000^{ns}	4.839**
ABD	1	19.253^{ns}	0.068^{ns}	4.775**
CD	1	0.163^{ns}	0.000^{ns}	0.682**
ACD	1	28.213*	0.067^{ns}	3.641**
BCD	1	37.808*	0.007^{ns}	0.168^{ns}
ABCD	1	19.001^{ns}	0.061^{ns}	0.323^{ns}
Error	30	5.310	0.146	0.084
C V (%)	-	6.90	8.97	1.71

** Significant at 1%, * significant at 5%, and ^{ns} not significant.

Table 5 Comparison of means for the fourfold interaction among drought stress condition, Barvar-2 phosphate biofertilizer, nitroxin biofertilizer, and the stacosorb polymer.

Treatment	Plant height (cm)	Umbel/plant	Seed/umbel	Seed/plant	1000-seed weight (g)	Total dry matter	Seed yield (g/m^2)	Harvest index	Essential oil percentage	Essential oil yield (mg/m^2)
$W_0B_0N_0S_0$	48.33 ab	32.57cde	14.23 b	318.30 abc	4.820 a	172.5 abc	55.57 abc	32.21 d	3.833 cde	0.8400 de
$W_1B_0N_0S_0$	50.10 ab	38.87ab	12.1 cdef	280.90 bc	4.603 ab	149.9 abcd	52.77 abcd	35.20 cd	2.253 g	0.5413 fg
$W_0B_1N_0S_0$	52.71 ab	32.33cde	12.93 bcde	287.60 bc	4.317 abc	117.6 d	53.20 ab	45.24 a	3.470 cde	0.7167 defg
$W_1B_1N_0S_0$	51.14 ab	35.40abcd	12.80 bcde	346.00 abc	4.133 abc	137.9 bcd	49.67 abcd	36.01 c	3.283 def	0.5390 fg
$W_0B_0N_1S_0$	54.60 ab	39.77a	13.50 bcd	356.50 abc	4.417 abc	192.7 a	56.57 a	29.35 de	2.387 fg	0.6080 efg
$W_1B_0N_1S_0$	53.13 ab	32.90cde	1163 ef	259.00 c	4.533 abc	162.0 abcd	48.10 d	29.69 de	2.300 g	0.5000 g
$W_0B_1N_1S_0$	49.51 ab	36.57abc	14.00 b	404.00 a	4.700 ab	161.3 abcd	55.50 abc	34.40 cd	3.183 defg	0.7070 defg
$W_1B_1N_1S_0$	46.68 b	38.60ab	12.77 bcde	298.40 bc	4.467 abc	127.7 cd	51.77 abcd	40.54 ab	2.990 efg	0.6467 defg
$W_0B_0N_0S_1$	53.07 ab	28.07e	13.73 bc	331.90 abc	3.833 abc	149.0 abcd	52.27 abcd	35.08 cd	5.183 ab	1.1210 ab
$W_1B_0N_0S_1$	51.20 ab	30.50de	13.77 bc	287.90 bc	3.920 abc	175.2 ab	48.57 d	27.72 e	3.750 cde	0.7447 def
$W_0B_1N_0S_1$	51.78 ab	31.00cde	13.07 bcde	279.10 bc	3.900 abc	148.6 abcd	49.27 d	33.16 d	4.433 bc	0.8600 cd
$W_1B_1N_0S_1$	55.43 a	29.10e	11.57 ef	286.10 bc	4.033 abc	163.9 abc	49.13 d	29.98 de	4.107 cd	0.7810 def
$W_0B_0N_1S_1$	53.30 ab	32.10cde	10.73 f	264.6 c	3.733 bc	167.5 abc	50.33 bcd	30.04 d	5.383 a	1.0710 bc
$W_1B_0N_1S_1$	54.48 ab	31.47cde	11.90 def	268.9 bc	3.567 c	149.4 abcd	50.50 abcd	33.80 d	4.370 bc	0.7567 def
$W_0B_1N_1S_1$	48.16 ab	33.97bcde	13.63 bc	351.3 abc	4.500 abc	187.3 aa	53.73 abcd	28.69 de	5.150 ab	1.3010 a
$W_1B_1N_1S_1$	54.16 ab	31.07cde	16.13 a	374.9 ab	4.567 abc	183.8 ab	53.37 abcd	29.03 de	3.800 cde	0.8767 cd

Treatments with at least one letter in common show no significant difference.
W=draught stress (W_1=stressed and W_0=non-stressed), B=barvar-2 phosphate biofertilizer (B_1=application and B_0=non-application), N=nitroxin biofertilizer (N_1=application and N_0=non-application), and S=stacosorb polymer (S_1=application and S_0=non-application)

Table 6 Results of correlation coefficient for the studied characteristics in fennel.

	Plant height	Umbel/plant	Seed/umbel	Seed/plant	1000-seed weight	Total dry matter	Seed yield	Harvest index	Essential oil percentage	Essential oil yield
Plant height	-	-	-	-	-	-	-	-	-	-
Umbel/plant	-0.278^{ns}	-	-	-	-	-	-	-	-	-
Seed/umbel	-0.184^{ns}	0.095^{ns}	-	-	-	-	-	-	-	-
Seed/plant	0.032^{ns}	0.477^{**}	0.246^{ns}	-	-	-	-	-	-	-
1000-seed weight	0.189^{ns}	0.330^{*}	0.276^{ns}	0.175^{ns}	-	-	-	-	-	-
Total dry matter	0.334^{*}	-0.126^{ns}	-0.030^{ns}	0.135^{ns}	0.152^{ns}	-	-	-	-	-
Seed yield	0.010^{ns}	0.381^{**}	0.352^{*}	0.306^{*}	0.466^{**}	0.166^{ns}	-	-	-	-
Harvest index	-0.199^{ns}	0.471^{**}	0.243^{ns}	0.193^{ns}	0.396^{**}	-0.033^{ns}	0.364^{*}	-	-	-
Essential oil percentage	0.046^{ns}	-0.511^{**}	-0.133^{ns}	-0.205^{ns}	-0.368^{*}	0.092^{ns}	-0.394^{**}	-0.510^{**}	-	-
Essential oil yield	0.081^{ns}	-0.370^{**}	0.091^{ns}	-0.039^{ns}	-0.161^{ns}	0.221^{ns}	-0.057ns	-0.412^{**}	0.836^{**}	-

** Significant at 1%, * significant at 5%, and ^{ns} not significant

Discussion

There was a positive and significant correlation at 1% probability level between seed yield and 1000-seed weight, seed yield and number of umbels per plant, number of seeds per plant and umbels per plant, harvest index and number of umbels per plant, harvest index and 1000-seed weight, and essential oil yield and essential oil percentage

(Table 6). Kazemi-Saeed [27] also reported a positive correlation between seed yield and the 1000-seed weight and seed yield and the number of umbels per plant in green cumin and also found a direct and significant relationship between seed yield and biological yield at 1% probability level. It seems that the observed positive and significant correlation between the aforementioned characteristics is attributed to the increase of dry weight through the better absorption of nutrients and therefore, there was an improvement of the photosynthesis and growth in treatments with biofertilizers, especially nitroxin.

Conclusion

Barvar-2 phosphate and nitroxin biofertilizers positively affected the number of umbels per plant, the number of seeds per umbel, the number of seeds per plant, harvest index, total dry matter, seed yield, plant height, essential oil percentage and yield, but had no significant effects on the 1000-seed weight. The application of the stacosorb polymer showed a significant and positive effect on the number of seeds per umbel and plant height under drought stress condition. It can be concluded that the application of the stacosorb polymer counteracts the unfavorable consequences of draught stress.

It is important to conduct further studies on the effect of nitroxin and barvar-2 phosphate biofertilizers and the stacosorb polymer on fennel under drought stress in other arid and semi-arid regions of the country. In addition, the effect of the application of biofertilizers on physical and chemical properties of soil presents an attractive research field.

Acknowledgements

This work was funded in agricultural faculty of Lorestan University. We thank our scholars for supplying primer sequences and positive controls.

(A) Is drought stress condition, (B) is Barvar-2 phosphate biofertilizer, (C) is nitroxin biofertilizer, and (D) is the stacosorb polymer.

[1] The variance of error 1 is usually higher than the variance of error 2 in split plot designs. The contradictions may be attributed to inconsistency among the sub-plots or a significant interaction between sub-factor and block. Therefore, interaction between sub-factor and block was removed from sub-plot error to eliminate this problem. The results are presented in Table 3. After removing interaction between sub-factor and block from sub-plot error, error 1 became higher than error 2 for total dry matter. However, error 1 was still lower than error 2 in the number of umbel per plant, 1000-seed weight, and harvest index. Therefore, a secondary analysis of variance was performed by factorial method. The result are presented in Table 4.

(A) Is drought stress condition, (B) is Barvar-2 phosphate biofertilizer, (C) is nitroxin biofertilizer, and (D) is the stacosorb polymer.

[1] As mentioned in Table 2, since error 1 was still lower than error 2 in the number of umbel per plant, 1000-seed weight, and harvest index after removing interaction between sub-factor and block from sub-plot error, therefore, a secondary analysis of variance was performed by factorial method. The result are presented in Table 4.

(A) Is drought stress condition, (B) is Barvar-2 phosphate biofertilizer, (C) is nitroxin biofertilizer, and (D) is the stacosorb polymer.

References

1. Kapoor R, Giri B, Mukerji K G. Improved growth and essential oil Yield and quality in (*Foeniculum vulgar* Mill.) on mycorrhiza inculation supplemented with p-fertilizer. Biores Technol. 2004;93:307-311.
2. Kader M A. Effect of *Azotobacter inoculant* on the yield and nitrogen uptake by wheat. J Biol Sci. 2002;2:259-261.
3. Abo Baker AA, Mostafa GG. Effect of Bio-and Chemical Fertilizers on Growth, Sepals Yield and Chemical Composition of *Hibiscus sabdariffa* at New Reclaimed Soil of South Valley Area. Asian J Crop Sci. 2011;3:16-25.
4. Malbubi M A. Characteristics of Barvar-2 phosphate biofertilizer. Jahad Daneshgahi Publication & Green Biotech Co. 2007;104. (In Persian).
5. Kizilkaya R. Yield response and nitrogen concentrations of spring wheat (*Triticum aestivum*). Inoculated with *Azotobacter chroococcum* strains. Eco Engin. 2008;33:150-156.
6. Keshavarz L, Farahbakhsh H, Golkar P. Effects of Different Irrigation and Superabsorbent Levels on Physio-Morphological Traits and Forage Yield of Millet (*Pennisetum americanum* L.). American-Eurasian J. Agric & Environ Sci. 2013;13:1043-1049.
7. Ghorbani A. Medicinal plants of Torkaman Sahra, Vol. 1. Publication of Shahid Beheshti University of Medical Sciences,Tehran. 2005;124. (In Persian).
8. Khorsand A. Medicinal plants. Shahrab and Ayandeh Gostar Publication. 2006;197. (In Persian).

9. Gross M, Friedman J, Dudai N, Larkov O, Cohen Y, Bar E. Biosynthesis of Estragole and t-in bitter fennel (*Foeniculum vulgare* Mill. var. *vulgare*) chemotypes. Changes in SAM: phenylpropene o-methyltranferase activities during development. Plant Science. 2002;163:1047-1053
10. Baser, K. H. C. and T. Ozek, Essential oils of *Mediasia macrophylla* and *Foeniculum vulgar* Mill from Uzbekistan. J Essen Oil Res. 1997;9:246-250.
11. Falahi J, Koochaki AR, Rezvani- Moghadam P. Effect of biological fertilizers on qualitative and quantitative yield of *Matricaria chamomilla* L. Iranian J Field Crops Res. 2009;7:127-134. (In Persian).
12. Talaee A, Asadzadeh A. The effect of stacosorb hydrogel on decreasing desiccation in olive tree. The Third National Congress on Superabsoebent Hydrogel Agricultural Application. Iran Polymer & Petrochem Institute. 2005. (In Persian).
13. Mahfouz SA, Sharaf-Eldin MA. Effect of mineral vs. biofertilizer on growth, yield and essential oil content of Fennel. Medicinal and Aromatic Plants Department, National Res Center. Cairo. 2007;12622, Egypt.
14. Tabrizi L. Study of ecological characteristics of *Thymus transcaspicus* in natural environment and the possibility of its domestication in low input farming. PHD Thesis. Department of Agronomy (Ecology), School of Agriculture, Ferdowsi University of Mashhad. 2007. (In Persian).
15. Khoshvaghti H, Akrami M, Yusefi M, Baserkouchehbagh S, Hoseini M. Influence of seed inoculation with biological fertilizer on fennel (*Foeniculum Vulgare*) and coriander (*Coriandrum Sativum*) germination. Int J Biosci. 2013;3:108-114. (In Persian).
16. Zehtab-Salmasi S. Eco-physiological effect of irrigation and sowing date on growth, yield, essential oil, and anthol in medicinal anise. PHD. Thesis. Department of Agronomy and Crop Breeding, Tabriz University. 2001. (In Persian).
17. Tatari, M. Effect of different levels of salinity and irrigation on growth and yield of green cumin under the climatic condition of Mashhad. M. Sc. Thesis. Department of Agronomy, School of Agriculture, Ferdowsi University of Mashhad. 2004. (In Persian).
18. Zaid HA. Effect of Rhizobacteria and nitrogen fertilization on the yield of barley. J Agric Sci. Mansoura Uni. 1992;17:3981-3986.
19. Madkour MA, Hassouna MG, Hassan MT. N2-fixation in newly introduced barley cultivars adaptable to arid conditions in Egypt. J Agric Res. 1987;32:351-363.
20. Hosein Talaei Gh, Gholami S, Kobra Pishva Z, Amini Dehaghi M. Effects of Biological and Chemical Fertilizers Nitrogen on Yield Quality and Quantity in Cumin (*Cuminum Cyminum* L.) J Chem Health Risks. 2014;4:55-64. (In Persian).
21. El-Hawary MI, El- Hawary I, Talman AM. El-Ghamary El-Naggar E. Effect of application of bio fertilizer on the yield and NPK uptake of some wheat genotypes as affected by the biological properties of soil. Pakistan J Biol Sci. 2002;5:1181-1185.
22. Khalili-Mahalleh H, Heidari Sharfi A, Nourmohammadi G, Darvish F, Islam MH, Valizadegan E. Effect of superabsorbent polymer (Tarawat A200) on forage yield and qualitative characters in corn under deficit irrigation condition in khoy zone (Northwest of Iran). Adv Environ Biol.. 2011;5:2579-2587.
23. Khadem SA, Ghalavi M, Ramroodi M, Mousavi SR, Rousta MJ, Rezvani- Moghadam P. Effect of animal manure and superabsorbent polymer on corn leaf relative water content, cell membrane and leaf chlorophyll content under dry condition. Australian J Crop Sci. 2010;4:642-647.
24. Surendra SR, Tomar KP, Gupta KP, Mohd A, Nigam KB. Effect of irrigation and fertility levels on growth and yield of coriander (*Coriandrum sativum*). Indian J Agron. 1994;30:442-447.
25. Timmermann BN, Steelink C, Loewus FA. Recent advanced in phytochemistry, Vol. 18: phytochemical adaptation to stress. Plenum Press. 1984;333.
26. Bunting M, Chung B. Effects of irrigation and nitrogen on the yield components of fennel (*Foeniculum vulgare* Mill.). Australian J Exp Agric. 1994;34:845-849.
27. Kazemi-Saeed F. Effect of drought stress and nitrogen fertilizer on growth, mineral elements, tissue content, and essential oil of green cumin. M. Sc. Plant Science Department. Tarbiat Modares University. 2002. (In Persian).