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Research Article

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The Impact of Plant Density on Morphological Characteristics of Fennel (*Foeniculum vulgare* Mill)

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ABSTRACT

The impact of plant density on qualitative and quantitative characteristics of fennel in a field factorial test with eight fertilizer factors of Nitrogen (50, 100 and 150), Compost (5 and 10 tons/acre), Nitroxin (20 and 40. Ml per liter) and control (without fertilizer); in addition to the variable of plant density (10 and 7 plants per square meter) was discussed based on random complete block design with four replications. Results of analysis of variance indicated that the impact of plant density was significant on plant height, number of umbels, seed yield, oil yield, harvest index and oil. In addition, mean comparisons showed that the highest performance was seen in application of 100Kg/acre of Nitrogen fertilizer in conjunction with the plant density of 40 plants/m^2.

Keywords: Fennel, Plant Density, Oil Harvest Index, Seed Harvest Index

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INTRODUCTION

Fennel (Foeniculum Vulgare Mill) is one of the most important and oldest medicinal herbs. This plant inhabits in Iran and it belongs to the family of Apiaceae (Lebaschi et al, 2011). This plant has only one cultivated variety (Mozafarian, 1996). Utilizing chemical fertilizers is known as the easiest and fastest way of compensating for lack of nutrients in soil and boosting the fertility of the soil for the purpose of improvement of yield per area. Soil fertility plays a crucial role in yielding of plants and therefore, utilization of a fertilizer is necessary for soils which lack adequate nutrients. In addition, Nitrogen itself is an important element for every plant and is found in proteins, Nucleic Acids and Chlorophyll. Furthermore, this nutrient is exposed to increased risk of insufficiency compared to other nutrients because its recycling process is half time slower than its consumption. Nevertheless, in Iran's current condition, the level of soil efficiency is relatively low due to several issues. As a result of increasing costs of chemical fertilizers, the efficiency of absorption and consumption of Nitrogen must be high in order to reduce the costs of organizations and increase profitability. For obtaining the former goal, we are required to first recognize the efficiency of absorption of nutrients as well as factors effective on it without reduction in performance and yielding (Khademi et al. 2000). Jin (1990) has reported the positive effect of speed application of a Nitrogen based fertilizer on the yield of seed and the content of effective agent in the medicinal herb of fennel. In addition, Amengor et al. (1990) found out in a research that as the amount of consumed Urea fertilizer increases in 0-100 kilograms per acre range; with a 181% increase, oil yield increases from 9.5liters to 16.6 liters per acre. Molafilabi et al. (2009) performed a test on Cuminum cyminum L. and observed the maximum yield of seed and oil as respectively 1016 and 36 kg/acre for lowest Urea containing treatment (50Kg/Acre). Baggari et al. (2010) investigated the effects of the amounts of 0, 60 and 80 and 100 kilograms per acre of Nitrogen fertilizer and declared that utilizing

100KG/Acre of Nitrogen fertilizer increases the yield of fennel significantly higher than other treatments. Nese and Benyamin (2005) discussed the effects of different amounts of Nitrogen (30 and 60 and 90 Kg/Acre) on yielding of coriander. They reported that the highest yield was associated with utilization of 90kg/Acre of Nitrogen fertilizer. In addition, Ibrahimi (2011) discussed the effects of different amounts of Nitrogen fertilizer (0, 40, 80 and 120kg/Acre) on the yield of coriander and consequently, he reported that with the treatment of 80kg/acre Nitrogen fertilizer, the amount of seed yield, the biological performance and the number of umbels were significantly higher than other treatments, however the weight of one thousand seeds had remained constant. Cultivation density influences an appropriate distribution of plants and better access to light, therefore difference in the method of distribution of solar energy and increased absorption of radiations results in improved fruitfulness and yield. Through affecting pollination by insects, temperature can impose a major influence on the number of seeds in each fruit. This in turn can result in either reduction or improvement of yielding (Aroi et al. 2007). Lebaschi et al. (2011) conducted a research on density of fennel and declared that increased density leads to reduced seed weight in fennel plant. It seems that this is due to increased number of plants per area unit and relative reduction of weight of seeds in each plant. The highest seed weight was observed in treatments with lower densities. Cherries et al. (2002) performed a pot experiment on Basil and indicated that by increasing the number of plants from 2 to 16, the biological performance shows an ascending trend, however the weight of plants with densities of more than eight was reduced. In addition, no significant relation was detected between density and oil yield. In another research, Muhammad Beigi (2006) declared that reduction of density from 50 plants to 30 plants per square meter increases the yield of coriander in terms of oil. Utilization of Bio-fertilizers such as Mycorrhiza, phosphate solubilizing microorganisms and vermicompost in a system based on sustainable agriculture; in addition to maintaining the health of environment, improves the quality and sustainability of performance and yielding specially in terms of production of medicinal herbs (Kapoor et al. 2004). Darzi et al. (2009) utilized bio-fertilizers for fennel and declared that in terms of amount of seed oil and levels of Anethole, fenchone and limonene in the oil, two treatments of bio-fertilizers including 30kg of bio-phosphate fertilizer and 10tons of vermicompost and 60kg of bio-phosphate fertilizer with 10 tons of vermicompost had a better performance compared to control treatment. Utilization of organic and non-organic fertilizers has different applications in agriculture for realization of different goals. As a result of having less harmful effects on the environment, organic fertilizers have been extraordinarily popularized. In addition, results of different researches show that very low amounts of organic acids can impose large impacts on physical, chemical and biological traits of the soil and as a result of including a plenty of hormone based compounds, it also imposes large effects on improvement of yield of crops (Samat and Malakooti, 2006). Also, Sharifi and Hagh Nia have declared that the biological fertilizer of Nitroxin improves the yield of Sablan variety wheat. In this regard, the mentioned fertilizer has positively impacted the seed and hay yield, plant height Spike length, number of grains per spike and number of spikes per square meter. Biari et al. (2011) have declared that utilization of Nitroxin fertilizer increases growth indexes including height, number of seeds per cluster, harvesting index, leaf area and dry-weight. It seems that the biological fertilizer of Nitroxin is able to be a suitable alternative for chemical fertilizers in production of crops.

EXPERIMENTAL SECTION

This research was performed in the city of Sardasht in 2015. This is a factorial experiment which was performed in a completely random fashion. The studied treatments include bio-fertilizers and chemical fertilizers (four treatments of Nitrogen fertilizer including 0, 50, 100 and 150Kg/acre and two treatments of Compost including 5 and 10tons/acre and two treatments of Nitroxin including 20 and 40 kg/acre in conjunction with plant densities of 20 and 40 centimeters on each row. Beforehand to proceeding with the experiment, a random soil sample was collected from the experiment site and was transferred to lab for determination of highly consumed nutrients and PH. Next, 3x4 plots were formed and in each plot, 6 cultivation rows were determined with a 50 centimeter distance from each other. At the next step, fennel seeds were planted on the rows with 20 and 40 centimeter gaps in a 2-3 centimeter depth during the first period of spring. In addition, the distance between each plot was 0.5meters. Immediately after planting and after wards, every seven days the plants were watered. First emergence of the plant was recorded in 15-20 days after planting. As the plants reached the height of 5cm, the gaps were tightened for obtaining desired densities. In addition, the weeds were dealt with by hand in three sets. The plants were ready for harvesting and sampling in 5.5 months after planting. Beforehand to harvesting, 5 plants were randomly selected and were subjected to tests in terms of different characteristics including wet and dry weights of plant, height, seed yield and components of seed yield including number of umbels in each plant, number of seeds in each umbellate and the number of seed per each umbel, seed weight and the percentage of seed's dry-matter which was calculated through relation 1-1.

$$\frac{\text{weight of dry seed sample}}{\text{weight of wet seed sample}} \times 100 \qquad \text{(Relation 1-1)}$$

The yield of seed per plant was multiplied by the number of plants in each acre and subsequently, the amount of seed yield per acre was obtained.

Oil extraction was completed using the Clonger oil extraction device. In this regard, 50 grams of fennel seed was first grinded and then mixed with 100cc of distilled water and next, the mixture was boiled for 30 minutes. After turning the heat off, the oil was extracted and measured (Omid Beigi, 1996).

In the phase of physiological treatment, for the purpose of determination of the harvest index, 5 plants were cut out from each plot and by application of the following formula, the harvest index of each treatment was measured:

HI= (EY/BY). 100

In the upper formula, Hi is the harvest index. EY is the economic yield and BY is the biological yield.

The data resulting from the test were subjected to computer based analyzes with the software of SAS and also the software of Microsoft Office Excel 2013 was used for drawing diagrams. In addition, the multiple-range Duncan test was used for mean comparisons.

RESULTS

Table 1, results of variance analysis regarding the measured characteristics of fertilizer and density based treatments of the medicinal herb of fennel

Harvest index	Seed oil percentage	Dry matter percentile	Seed per acre yield	Weight of 1000 seeds	Seed yield per plant	Number of umbels per plant	Plant height (cm)	Freedom degree	Sources of changes
0/003**	0/01**	3/34**	6906/28**	1/85**	0/30**	7/02**	327/54**	7	Fertilizer
0/01**	0/02ns	12/87**	1725/78**	0/98**	9/79**	7/78**	81/6**	1	Density
0/002**	0/02*	3/34**	375/78**	0/11**	0/01**	1/26**	2/86**	7	reaction
0/00008	0/005	0/01	1/99	0/009	0/01	0/01	0/061	48	Experimental error

Table 2, results of comparisons of means of simple impacts of density on fennel

Harvest index	Seed oil percentage	Dry-matter percentile	Seed per acre yield	Weight of 1000 seeds	Seed per plant yield	Umbel per plant number	Plant height	Density treatment
0/27a	3/05a	86/03a	220a	2/6a	2/4b	18/21a	75/84a	20
0/25b	3/1a	85/1b	202/6b	2/3b	3/09a	17/62b	73/39b	40

Number of umbels per plant

With respect to the results of analysis of data variance, the simple impact of fertilizing was significantly on the number of umbels per plants of fennel. The highest observed amount was related to the treatment of 100kgs/acre of Nitrogen fertilizer (19.1) and also the lowest observed amount was related to the control treatment (17.07). In addition, the simple impact of density was also significant on the number of umbels per fennel plant. The highest level was associated with a plant density treatment of 20centimeters (18.21) and also the lowest level was associated to the treatment of 40centimeters (17.62). The mutual impacts of fertilizing and plant density were also realized to have significant impacts on the number of umbels in fennel plant.

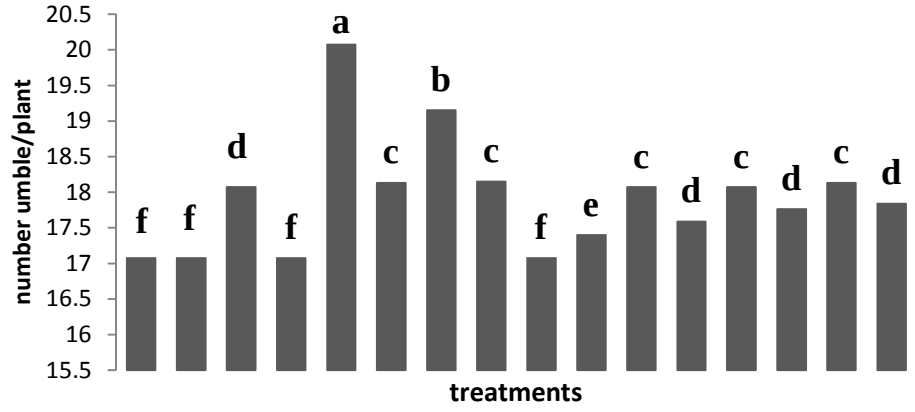

Figure2, mutual impacts of fertilizing and plant density treatments on the number of umbels per fennel plant

Seed yield per plant

With respect to the results obtained from the analysis of data variance, it was confirmed that the simple impact of fertilizing is significant on seed yield per fennel plant. The highest amount (3.22grams) was observed in the treatment of 20kg/acre Nitroxin and also the lowest amount (2.32grams) was observed in the treatment of 5tons/acre of compost. In addition, the simple impact of plant density was significant on the seed yield per fennel plant. The highest amount (3.09) was observed for the treatment of 40cm density and the lowest amount was associated with the treatment of 20cm density. The mutual impacts of fertilizing and plant density have a significant impact on the seed yield per fennel plant.

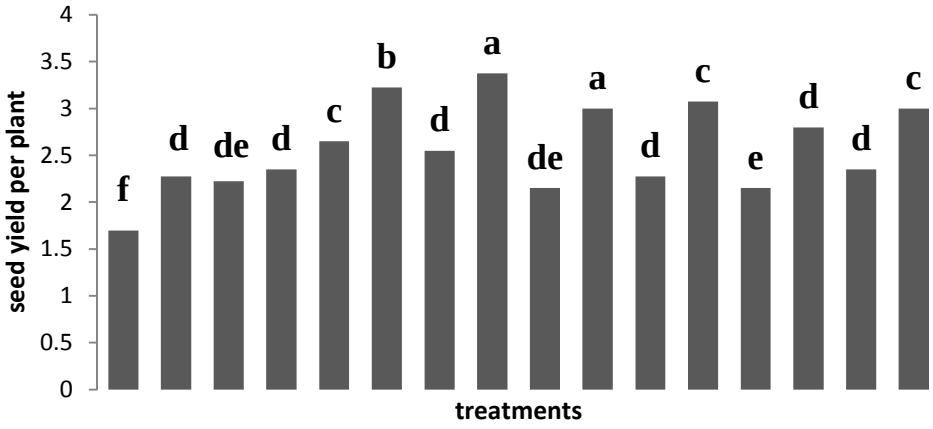

Figure 3, mutual impacts of fertilizing and plant density treatments on seed yield per fennel plant

Weight of 1000 seeds

With respect to the results obtained from the analysis of data variance, it was confirmed that the simple impact of fertilizing is significant on the weight of 1000 fennel seeds. The highest amount (3.08) was observed in the treatment of 100kg/acre Nitrogen and also the lowest amount (2.1grams) was observed in the control treatment. In addition, the simple impact of plant density was significant on the weight of 1000 fennel seeds. The highest amount (2.6) was observed for the treatment of 20cm density and the lowest amount (2.31) was associated with the treatment of 40cm density. The mutual impacts of fertilizing and plant density have a significant impact on the weight of 1000 fennel seeds.

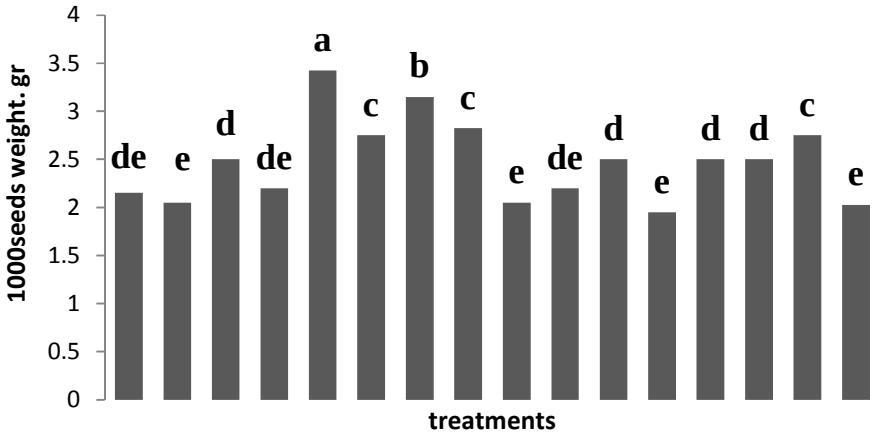

Figure 4, mutual impacts of fertilizing and plant density treatments on the weight of 1000 fennel seeds

Seed yield per acre

With respect to the results obtained from the analysis of data variance, it was confirmed that the simple impact of fertilizing is significant on the fennel seed yield per acre. The highest amount (245.5kg) was observed in the treatment of 100kg/acre Nitrogen and also the lowest amount (164.62kg) was observed in the control treatment. In addition, the simple impact of plant density was significant on the fennel seed yield per acre. The highest amount (220kg) was observed for the treatment of 20cm density and the lowest amount (202.3) was associated with the treatment of 40cm density. The mutual impacts of fertilizing and plant density have a significant impact on the fennel seed yield per acre.

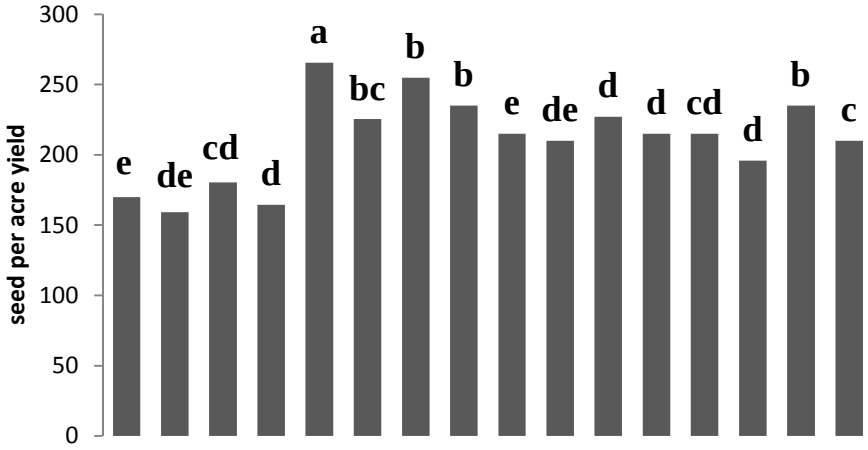

Figure 5, mutual impacts of fertilizing and plant density treatments on the yield of fennel seed per acre

Seed oil percentage

With respect to the results obtained from the analysis of data variance, it was confirmed that the simple impact of fertilizing is significant on the fennel seed oil percentage. The highest amount (3.5) was observed in the treatment of 20kg/acre Nitroxin and also the lowest amount (20.7) was observed in the treatment of 150kg/acre of Nitroxin. In addition, the simple impact of plant density was not significant on the fennel seed oil percentage. The mutual impacts of fertilizing and plant density have a significant impact on the fennel seed oil percentage.

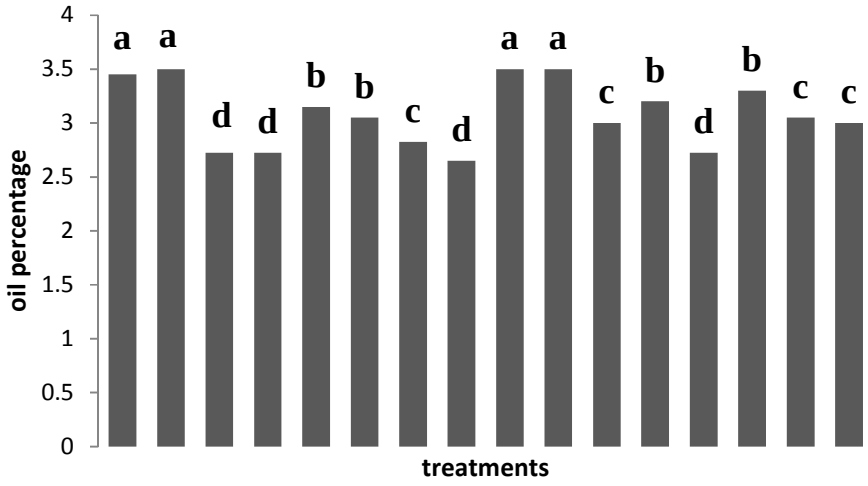

Figure 6, mutual impacts of fertilizing and plant density treatments on the fennel seed oil percentage

Seed's dry-matter percentage

With respect to the results obtained from the analysis of data variance, it was confirmed that the simple impact of fertilizing is significant on the fennel seed's dry-matter percentage. The highest amount (86.68) was observed in the treatment of 100kg/acre Nitrogen and also the lowest amount (85.12) was observed in the treatment of 20kg/acre of Nitroxin. In addition, the simple impact of plant density was significant on the fennel seed's dry-matter percentage. The highest amount (86.03) was observed for the treatment of 20cm density and the lowest amount (85.12) was associated with the treatment of 40cm density. The mutual impacts of fertilizing and plant density have a significant impact on the fennel seed's dry-matter percentage.

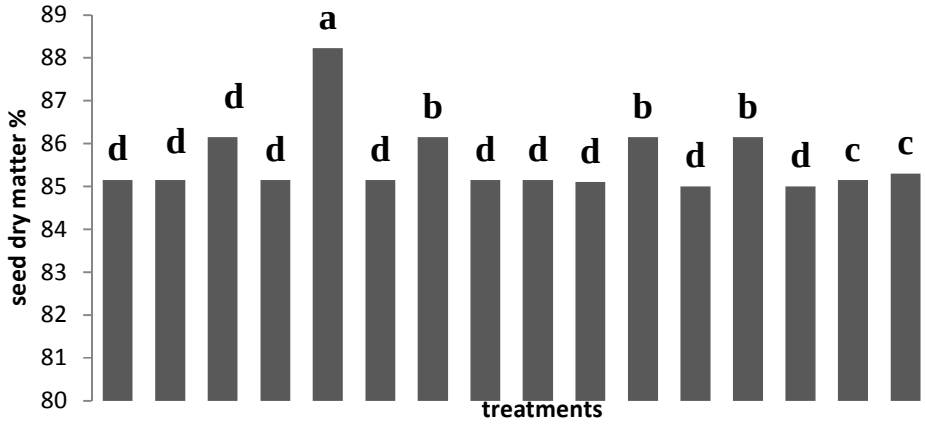

Figure 7, mutual impacts of fertilizing and plant density treatments on the fennel seed's dry-matter percentage

Harvest index

With respect to the results obtained from the analysis of data variance, it was confirmed that the simple impact of fertilizing is significant on the harvest index of fennel. The highest amount (0.29) was observed in the treatment of 100kg/acre Nitrogen and also the lowest amount (0.24) was observed in the treatment of 150kg/acre of Nitrogen. In addition, the simple impact of plant density was significant on the harvest index of fennel. The highest amount (0.27) was observed for the treatment of 20cm density and the lowest amount (0.25) was associated with the treatment of 40cm density. The mutual impacts of fertilizing and plant density have a significant impact on the harvest index of fennel.

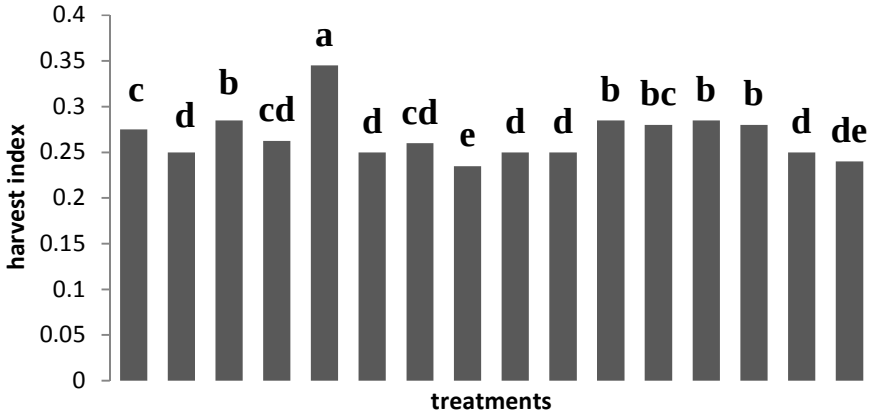

Figure 8, mutual impacts of fertilizing and plant density treatments on the harvest index of fennel

DISCUSSION AND CONCLUSION

This research has clearly manifested the positive effect of compost on yield, components of yielding, percentage and also the amount of oil of fennel. Among the mentioned treatments, the treatment of 10 tons/acre of compost had the highest impact in terms of increasing the aforementioned characteristics. These treatments are completely safe for the environment and by sustaining the sustainability and health of the agriculture system; these treatments can supplement plants' nutritional requirements to a large extent. Adjusting the gaps between plants is considered also as a powerful tool for controlling the competition between plants of a certain variety for the purpose of maximum production of effective matter (Hornbook, 1986). In terms of yield and as a controlled element, plant density is highly important and in this regard, one of the most basic principles for cultivation is to determine a suitable density (Liras et al. 2004). In terms of cultivation of medicinal plants, plant density and the amount of access to nutritional material can impact the amount of extracted oil and its subsequent quality (Tyler et al. 1988). Not unlike other species, plants also live in a world of competition. After efflorescence, the plant should compete its neighbors in terms of absorption of light, water and nutrients. In this research, the oil and seed yield efficiency was maximally recorded for the density of 10 plants per m^2. And as the density was reduced, the seed yield and oil yield of fennel increased. The highest seed yield per acre was related to the treatment of 100kg/acre Nitrogen fertilizer with a density of 10 plants per m^2. In addition, the highest level of seed oil was obtained with the biological fertilizer of Nitroxin. The overall results indicate that as the seed yield increases, the percentage of oil also increases.

The most important element is the amount of production, is the sum of yield components. In the treatment of 100kg/acre Nitrogen fertilizer, as a result of balance in nutrients and balance among the components of yielding; a high yield was obtained.

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