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Effects of biological and chemical fertilizers nitrogen on yield quality and quantity in Fennel (*Foeniculum vulgare* Mill.)

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Abstract

Considering the importance of medicinal plants growth and biological application of fertilizers with sustainable agricultural production in order to eliminate or reduce chemical input to achieve desirable and sustainable quality, an experimental research based on randomized complete block design with two factors of chemical nitrogen (46% urea nitrogen) at three levels (Zero, 25 and 50 $kg.ha^{-1}$), biological nitrogen (Azotobacter) with trade name Nitroxin at two levels inoculated and non-inoculated was carried in 2013 at the research farm of Khoramabad in Lorestan, Iran. The results of analysis of variance showed that the effects of biological fertilizers (Azotobacter) Nitroxin of chemical (urea 46%) nitrogen in different treatments on biological yield, grain yield, harvest index (HI) and essential oil yield were significant at $P \leq 0.01$. The means showed that the greatest biological yield (3875 $kg.ha^{-1}$), grain yield (1017 $kg.ha^{-1}$) and essential oil yield (19.38 $kg.ha^{-1}$) were obtained by a treatment of Nitroxin + chemical nitrogen (25 $kg.ha^{-1}$). In general, results of the present study revealed that application of biological fertilizers plays a remarkable role in improving yield quality and quantity in Fennel and they can be viewed as a suitable replacement for chemical fertilizers.

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Introduction

Medicinal plants are used to cure many ailments that are either non-curable or seldom cured through modern systems of medicine. Approximately 80% of the world population depends on medicinal plants for their health and healing (Aliyu, 2003). Societal motivations to use herbs are increasing due to concern about the side effects of synthetic drugs. Many botanicals and some dietary supplements are good sources of antioxidants and anti-inflammatory compounds (Balasubramanian *et al.*, 2001). Fennel (*Foeniculum vulgar* Mill.) is one of the most important medicinal plants. It is a perennial and hardy herb that grows in many parts of the world, especially on dry soil near the coasts. The bulb, foliage and seeds are used in many of the culinary traditions of the world. Fennel stimulates appetite and aids digestion. It is also used for kidney stones, menopausal problems, nausea and obesity (Zahid *et al.*, 2009). Wild and cultivated fennel has different size, odor, taste, quality and yield potential. Therefore, it is important to select superior accession for cultivation. Nitrogen fertilization management is important to optimize crop production. Nitrogen is one of the most important nutrients in crop production, because it affects photosynthetic efficiency and leaf development, which leads to dry matter production (Dordas and Sioulas, 2008). There are some supporting studies that N fertilization affects yield, content, and composition of essential oils of medicinal plants (Ashraf *et al.*, 2006). However, nitrogen application presents conflicting results in regard to growth, essential oil yield and contents of medicinal plants. There are some supporting studies that N fertilization affects yield, content, and composition of essential oils of medicinal plants (Ashraf *et al.*, 2006). However, nitrogen application presents conflicting results in regard to growth, essential oil yield and contents of medicinal plants. Economakis *et al.* (1999) showed that N fertilization had no effect on essential oil content of *Origanum dictamnus*. Biological fertilizers (*Azotobacter*) absorb and increasing the concentration of essential elements such as nitrogen, phosphorus, potassium, zinc, magnesium, iron and protein in crops (Habibi, 2004). Research has shown that the performance and the ability of *Azotobacter* in nitrogen fixation and balance in the soil depend on the soil properties and plant (Requena *et al.*, 1997). Despite the significant positive effects of *Azotobacter* on plants, the exact function in the development of plant growth is still unknown. Pereira *et al.* (1998) in their studies on inoculated pearl millet announced the increased performance by more than 33 percent. Research has shown that the effect of biological *Azatobacter* fertilizer was significant on pepper, and the highest pepper yield was reported 3.34 ton/ha (Mandel, 2003). Nitrogen improved the performance of more than 30 percent of Geranium (Pelargonium) and other medicinal plants (Rao *et al.*, 1998). Application of 100 kg.ha^{-1} of nitrogen increased the production of secondary metabolites (*cisque-Terpin*) and percentage Chamomile (*Matricaria chamomilla*) increased dry matter from 3 to 6 percent (Bullock, 1999). Also effect of nitrogen on dry weight and percent *Thymus kotschyanus* species was significant but left no significant impact on the amount and percentage of oil and *carvacrol* (Habibi, 2004). Research showed that the amount of nitrogen up to 120 kg.ha^{-1} produced more *thymol* yield in *thyme* oil, but had no significant effect on the amount of seed oil (Akbari niea., 2004). Nitrogen increased *thymus vulgaris* oil yield and percent *thymol* and the best treatment was 100 kg N/ha^{-1} (Rezaei Nejad, 2000). Research showed that by increasing nitrogen application from 105 to 120 kg.ha^{-1} the essence yield and *thymol* increased significantly, but had no significant effect on the amount of seed oil (Akbari niea, 2004). Aims of the study evaluation of biological and chemical fertilizers nitrogen on yield quality and quantity in Fennel.

Materials and methods

Plant material collection

The experiment was carried out in 2013 at the research farm Khoramabad, Lorestan Iran, located in the longitude 48º and 21' and the latitude 320 and 30' with a height of 1117 m above sea level, with annual precipitation of 524 mm and average annual temperature of 17º C.

Physical and chemical properties

The physical and chemical properties of the experimental soil where shown in table 1. The field was prepared in autumn and in March the crop was planted.

Type of design and treatments

The experiment was a factorial with two factors arranged in a randomized complete block design with three replications. The first factor was three levels of chemical nitrogen (46% urea nitrogen) Zero, 25 and 50 $kg.ha^{-1}$ and second factor was biological nitrogen fertilizer (combination of *Azotobacter* spp. and *Azospirillum* spp.) at two levels; inoculated and non-inoculated. Each experimental plot was three meters long and two meters wide with the spacing of 50 cm between the rows and a distance of 20 cm between plants in the rows.

Space between plots and replications

There was a space of one meter between the plots and two meters between replications. The Fennel seeds were planted distance were two cm apart, covered with wet sand and about a centimeter thick and after emerging from the soil, thinning operation to set the desired density was performed.

Biological nitrogen fertilizer applied

Biological nitrogen fertilizer (Nitroxin) solution was applied as sprinkling system. Three-quarters of fertilizer was applied at planting seeds and the rest was applied to plant at shooting. Fennel seeds were directly sown by hand. There was no incidence of pest or disease on cumin during the experiment.

Basin irrigation

Basin irrigation until harvest was done depending on weather conditions and weeds were controlled. In order to measurement of characteristics of effective on yield components and substance effective, after removing the marginal effects of each plot, 10 plants from each plot were harvested randomly. All necessary cultural practices and plant protection measures were followed uniformly for all the plots during the entire period of experimentation. Dried seeds (50 gr) of each plot were separated and powdered. The powder subjected to hydro distillation (400 ml distilled water), using a Clevenger-type apparatus for 2.5 hours and its essential oil was separated. Collected essential oil value was expressed regarding seed weight as essential oil yield.

Data analysis

Data analysis was done by using software SPSS and MSTAT-C. The ANOVA test was used to determine significant ($p \leq 0.01$ or $p \leq 0.05$) treatment effect and Duncan Multiple Range Test to determine significant difference between individual means. In this experiment plant height, umbel number per plant, grain number per umbel, weight of 1000 grains, biological yield, grain yield, harvest index (HI), essential oil percentage and essential oil yield were studied. Fifteen plants were randomly selected from each plot and the observations were recorded.

Results and discussion

Plant height

Biological yield

The results of the analysis variance showed that the biological yield was significantly affected by all treatments ($P \leq 0.01$) in this experiment (Table 2). Mean comparison table showed that the highest (3875 $kg.ha^{-1}$) and lowest (2647 $kg.ha^{-1}$) biological yield were obtained by a treatment of Nitroxin + chemical nitrogen (25 $kg.ha^{-1}$) and control, respectively (Table 3). Effect of Nitroxin on the biological yield of plant was due to increased nitrogen uptake and the growth rate improvement (Vande Broek, 1999). The result of present work are in agreement with the reports of Youssef *et al.* (2004) on *Salvia officinalis*, Kumar *et al.* (2009) on *Artemisia pallens* and Valadabadi and Farahani (2011) on *Nigella sativa*.

Grain yield

The results presented in Table 2 have revealed that different levels of treatments had significant effects on the grain yield ($P \leq 0.01$). Mean comparison table showed that the maximum (1017 $kg.ha^{-1}$) and minimum (40.867 $kg.ha^{-1}$) grain yield were obtained by a treatment of Nitroxin + chemical nitrogen (25 kg.ha^{-1}) and control, respectively (Table 3). Increased seed yield in Nitroxin treatments can be owing to the improvement of yield components such as; umbel number per plant, grain number per plant and grain number per umbel of plant. These result are in agreement with the investigation of Kumar *et al.* (2002) and Darzi *et al.* (2012) on *Coriandrum sativum*, Migahed *et al.* (2004) on *Apium graveolens*, Tehlan *et al.* (2004), Shaalan (2005) and Valadabadi and Farahani (2011) on *Nigella sativa*.

Table 1. several physical and chemical properties of the experimental soil.

Ec mmos/cm	pH	Cu ppm	Zn ppm	Mn ppm	Fe ppm	N ppm	K ppm	P ppm	O.C (%)	Deep (cm)
0.61	7.7	0.68	0.8	6.6	7.6	80	230	8	0.79	0-30

Harvest index (HI)

The results of the analysis variance showed that the harvest index was significantly affected by all treatments (P≤0.01) in this experiment (Table 2). Mean comparison table showed that the highest (33.15 %) and lowest (26.39 %) harvest index were obtained by a treatment of Nitroxin + chemical nitrogen (25 kg/ha) and control, respectively (Table 3). The same result was observed in a study on the effects of application of biological fertilizer on biological yield and growth indices of black cumin in 2008 (Khoram *et al.* 2008). Results showed 22.81% partitioning of photosynthate was appropriated for grain and the rest for straw. The grain and the vegetative plant and improvements in harvest index emphasize the importance of carbon allocation in grain production. However, increasing grain yield and crop harvest index with high nitrogen grain requires a concomitant increase in crop nitrogen accumulation (Sinclair TR, 1998).

Table 2. Analysis of variance for effects of biological and chemical fertilizers nitrogen on yield quality and quantity in Fennel.

Resource changes	df	biological yield	grain yield	harvest index (HI)	essential oil percentage	essential oil yield
Repetition	2	78445.167 ns	571.500 ns	5.737 ns	0.008 ns	0.113 ns
Nitroxin	1	863298.000 **	15488.000**	20.715**	0.115 ns	27.627**
Nitrogen	2	828903.500 **	6159.500**	37.379 **	0.182 ns	27.657**
Nitroxin × Nitrogen	2	185926.500**	2187.500**	7.603**	0.017 ns	4.460**
Error	10	51406.967	3182.900	8.144	0.027	1.624
CV (%)	-	7.27	6.03	9.39	10.34	8.55

**: Significant at = 1%, ns: Not significant.

Essential oil percentage

The present results showed that by all treatments had not significant effect on essential oil percentage (Table 2). Mean comparison table showed that the highest (1.91 %) and lowest (1.41 %) essential oil percentage were obtained by a treatment of Nitroxin + chemical nitrogen (25 kg.ha^{-1}) and control, respectively (Table 3). Besides, plant ecotype differences in regional environmental, soil, and climatic conditions, growing techniques, irrigation, as well as fertilization affect the content and composition of secondary metabolites in medicinal and aromatic plants. There are some supporting studies that nitrogen fertilization affects content and composition of secondary metabolites in medicinal plants (Ozguven *et al.*, 2002 and Ashraf *et al.*, 2006).

Essential oil yield

The results of the analysis variance showed that the essential oil yield was significantly affected by all treatments (P≤0.01) in this experiment (Table 2). Mean comparison table showed that the highest (19.38 $kg.ha^{-1}$) and lowest (12.30 $kg.ha^{-1}$) essential oil yield were obtained by a treatment of Nitroxin + chemical nitrogen (25 $kg.ha^{-1}$) and control, respectively (Table 3). Although the effective elements of plants are produced by genetic processes but their production is affected by different factors such as: yield loss, wrong management and particularly nutrients deficit (Malakouti, 2009). The results of the present study confirm with the results of Azizi (2000) reporting the effect of nitrogen on the essence yield in anis plant. Shalaby and Razin (1992) reported that application of 105 kg/ha of nitrogen increased essence and *thymul* in *Thymus* plant.

Table 3. Mean comparison of the effects of biological and chemical fertilizers nitrogen on yield quality and quantity in Fennel.

Treatments	biological yield ($kg.ha^{-1}$)	grain yield ($kg. ha^{-1}$)	harvest index (HI) (%)	essential oil percentage (%)	essential oil yield ($gr.ha^{-1}$)
N1+	3270 b	942 ab	28.95 ab	1.61 a	15.14 b
N2+	3875 a	1017 a	33.15 a	1.91 a	19.38 a
N3+	2873 bc	936 ab	32.64 a	1.49 a	13.19 bc
N1-	2647 c	875 b	26.39 b	1.41 a	12.30 c
N2-	3216 b	925 ab	28.89 ab	1.67 a	15.39 b
N3-	2841 bc	919 ab	32.37 a	1.45 a	13.31 bc

*In each column, means with the similar letters are not significantly different at 5% level of probability using Duncan's test. +: Seeds inoculation to biofertilizer nitroxin, -: non-inoculated, Control (without fertilizer), N2: 25 kg/ha^{-1} chemical nitrogen fertilizer, N3: 50 kg/ha^{-1} chemical nitrogen fertilizer.

Conclusion

Biological fertilizers are widely applied in crop production and they are proper substitutions for chemical fertilizers. Application of biological fertilizer significantly improved quality and quantity features in Fennel. Maximum of biological yield, grain yield, harvest index (HI) and essential oil yield was obtained in treatment of Nitroxin + chemical nitrogen (25 kg/ha^{-1}). Totally, the obtained results revealed that using biological fertilizer combined with chemical fertilizer significantly improved the quantity and quality characters compared to control.

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