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EFFECT OF DIFFERENT NITROGEN SOURCES ON VEGETATIVE TRAITS, GRAIN YIELD AND ESSENTIAL OIL YIELD OF CORIANDER (*CORIANDRUM SATIVUM)*

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ABSTRACT. Coriander (*Coriandrum sativum*) is one of the medicinal plants that its essential oil yield has abundance medicinal and food value. One of the main concepts in the production of medicinal plants is to increase of yield by biofertilizers. In order to evaluate the separate and combined effect of nitrogen and biofertilizer Nitroxin (mixture of bacteria *Azotobacter* and *Azospirillum*) fertilizer on vegetative traits, grain yield and essential oil yield of coriander, an experiment was conducted as a factorial in a randomized complete block design (RCBD) with three replications in the field research of Islamic Azad University, Jiroft, Iran. The experiment factors were consisted of three levels of nitrogen (0, 75 and 150 kg·ha^{-1}) and three levels of Nitroxin biofertilizer (0, 2 and 4 L·ha^{-1}). The results showed that application of 150 kg·ha^{-1} N significantly increased height and stem diameter, number of lateral branches and shoot dry weight, compared with control and application of 75 kg·ha^{-1} N. Nitroxin biofertilizer significantly improved vegetative traits of coriander when compared with control, so that application of 4 L·ha^{-1} of Nitroxin caused increase the mean of traits compared to control. In the most evaluated growth traits, the highest means were obtained with combining of 150 kg·ha^{-1} N with 4 L·ha^{-1} of Nitroxin. Application of 150 kg·ha^{-1} N increased the number of umbels per plant, 1000 seeds weigh, seed yield and essential oil yield, 29.9, 33.0, 72.9, 40.7, 147.4 and 177.1 percent, compared with the control, respectively. In the presence of Nitroxin, yield and yield component and essential oil yield of coriander increased significantly. Maximum average of these traits obtained when 4 L·ha^{-1} of Nitroxin was applied.

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Integrated of nitrogen and Nitroxin increased yield and yield component and essential oil yield significantly, when compare with application separately of them. So that the maximum mean of these traits obtained with combined application of 150 $kg \cdot ha^{-1}$ nitrogen and 4 $L \cdot ha^{-1}$ of Nitroxin. The results of this research was showed that application Nitroxin biofertilizer have an important role in increase of quantity and quality yield of coriander medicinal plant and can be used as an alternative of nitrogen fertilizer in sustainable agriculture.

Key words: Azospirillum; Azotobacter; Essential oil; Grain yield; Nitrogen.

INTRODUCTION

Coriander (*Coriandrum sativum*) is an annual medicinal plant of *Apiaceae* family and it is native of Mediterranean regions (Purseglove *et al.*, 1981). This plant is one of the most valuable plants in the pharmaceutical industry of developed countries and cultivate in different regions of the world, as well as Iran country. In order to achieve optimal growth and increase the quality and quantity of coriander, it is necessary to supply nitrogen during the growing season (Omidbygi, 2005). Nitrogen fertilizers are effective in increase yield and improve vegetative characteristics of medicinal plant, such as coriander (Rahimi *et al.*, 2009; Akbarinia *et al.*, 2006; Darzi *et al.*, 2006; Abbaszadeh *et al.*, 2006; Gujar *et al.*, 2005; Bist *et al.*, 2000). But unlike of these results, Arganosa *et al.* (1998) reported that application of nitrogen fertilizer on seed yield of coriander plant is not significant. On the other hand, essential oil yield of dill (*Anethum graveolens*) (Bist *et al.*, 2000; Makkizadeh *et al.*, 2011), lavender (*Lavandula stoechas*) (Mardani-Nejad *et al.*, 2003), coneflower (*Echinacea purpurea*) (Default *et al.*, 2003), and valerian (*Valeriana officinalis*) (Hormoznezhad, 2005) can be improved by nitrogen fertilizers, but there was no significant changes in the amount of essential oil of coriander (Akbarinia *et al.*, 2006).

Although nitrogen fertilizers have a key role in enhancing the yield of medicinal plants, but inappropriate use of it causes ecological and human health risk, depletion of non-renewable resources and reduce the resistance of plants to pests and diseases (Brandt, 2008; Shivaputra *et al.*, 2004; Sharma 2002). Because, in sustainable farming systems, it is preferred product quality over product quantity, so production of medicinal plants that their quality has considerable importance is desirable in this type of systems (Arun, 2002; Wallace, 2001). Also, one of the main purpose of these systems is eliminating or reduce the use of chemical inputs and replacing them with organic and biofertilizers to overcome environmental problems and improve the health of agricultural products (Sharma 2002).

Currently, biofertilizers have been proposed as an alternative option for chemical fertilizers, such as nitrogen to increase soil fertility in sustainable agricultural production

(Wu *et al*., 2005). In recent decades, a broad spectrum of soil bacteria in the rhizosphere was identified, that could improve the growth of most medicinal plants. Some of these bacterial species, that are capable of aiding the plant, belong to the genus *Azotobacter*, *Azospirillum*, *Pseudomonas* and *Bacillus* (Tilak *et al*., 2005). Biofertilizers are material includes a variety of free living microorganisms (Vessey, 2003), that have the ability to convert macronutrients from unavailable to available form during biological processes, and has led to the development of the root system and seed germination (Rajendran and Devaraj, 2004; Elliot and Wildung, 1992).

Nitroxin with a set nitrogen stabilizer of bacteria of the genus *Azotobacter* and *Azospirillum* that the addition of nitrogen fixation of air and balancing the absorption of macro and micro nutrients required by plants, with synthesis and secretion of stimulating plant growth like various of growth regulator hormones, such as auxin and also secretin of different amino acid and variety of growth antibiotics and cause development of root and aerial parts of the plant and to protect the roots from soil pathogens attack, is increase the quantity and quality of the product (Black, 1993; Gilik *et al*., 2001).

Many researchers suggested a positive effect of the application of biofertilizers and free living bacteria, including *Azotobacter* and *Azospirillum*, on growth, development, grain and essential oil yield of coriander (Shirkhodaei *et al*., 2014; Darzi *et al*., 2012; Makkizadeh *et al*., 2011; Rahimi *et al*., 2009; Kumar *et al*. 2002) and other medicinal plant (Khorramdel *et al*., 2008; Fatma *et al*., 2006; Migahed *et al*., 2004; Youssef *et al*., 2004; Badran and Safwat, 2004; Abdou *et al*., 2004). Some studies showed that with combined application of biofertilizers, such as *Azospirillum*, *Azotobacter* and *Bacillus*, and chemical fertilizers, vegetative traits, grain and essential yields of medicinal plants can be improved (Kumar *et al*., 2009; Koocheki *et al*., 2008; Mahfouz and Sharaf Eldin 2007; Gewaily *et al*., 2006).

Nowadays, using beneficial soil organisms as biofertilizers, is as the most natural and best way to keep the alive and active vital soil system on agricultural land. According to the importance of coriander culture and also problems that continued application of fertilizers, particularly nitrogen has created in health-leaf plants; this study was conducted to evaluate the effect of nitrogen fertilizer application and Nitroxin biofertilizer on growth characteristics, grain yield and essential oil content of the coriander medicinal plant.

MATERIALS AND METHODS

In order to study the effects of nitrogen and Nitroxin biofertilizer on yield and yield components of coriander medicinal plant, a randomized complete block design was conducted as factorial experiment with three replications in the

field research of Islamic Azad University, Jiroft, Iran, during at 2012 and 2013 years.

Experimental factors were consisted of three levels of nitrogen (0,75 and 150 kg N ha^{-1}) and Nitroxin biofertilizer at three levels (0, 2 and 4 $L \cdot ha^{-1}$). A source of nitrogen, urea (containing 46% pure nitrogen) was applied at three stages; planting, after the first harvest and before flowering. Nitroxin (prepared in Tehran University) was used in three phases inoculated with seed at planting, 4 to 5 leaves stage and beginning of stem elongation. Before planting of plant, three soil samples selected randomly and after merge samples, soil samples were transported to the laboratory and its physical and chemical properties were determined. According to laboratory results, soil texture was sandy with 0.4% organic matter, 0.06 ppm total nitrogen, 7.8 ppm P, 85 ppm K, pH = 6.9 and EC (Electrical conductivity) = 1.4 $dS \cdot m^{-1}$.

Calculation the amount of phosphorus and potassium was used based on the results provided by the Malakouti and Tehrani (2000) for vegetable fertilizer recommendation.

Each experimental plot (2×2.1 mts) was consisted of four planting rows with a distance of 30 cm from each other. In the late November of 2012, coriander seeds were sown with intervals of 10 cm and a depth of 2 cm, on each row. Irrigation was performed every week for each plot. The coriander product is harvested in several stages, therefore during the experiment to measure the vegetative yield per unit area in three steps (45, 75 and 110 days after planting), plant sampling was performed.

At each sampling, 10 plants selected randomly from each plot and vegetative yield (fresh leaves and stems), was measured per unit area. To calculate the total yield of the growth season, a total of yield of the three samples were considered. In the late May of 2013, the intermediate rows of each experimental plot (equal to one square meter) coriander plants were harvested and the diameter and length of the main stem, number of lateral branches per plant, shoot dry weight, number of umbels per plant, number of seeds per umbel, number of seeds per plant and seed yield was calculated. For the evaluation of essential oil content, the extraction was performed under laboratory conditions, according to the methodology proposed by IAL – Adolfo Lutz Institute (1985), with Soxhlet extraction through the use of petroleum ether solvent. Extraction was carried out in all replicates of each treatment with 500 g of milled plant material. Statistical analysis using SAS software and mean comparison was done by Duncan's test at level 5%.

RESULTS

Effects of nitrogen fertilizer and Nitroxin biofertilizer on the vegetative growth characteristics of coriander

Results of analysis of variance showed that the effect of nitrogen fertilizer on all vegetative growth traits evaluated at the statistics level of 1% was significant (*Table 1*). The effect of Nitroxin on main stem length was significant at the statistics level of 5% and on the other traits was significant at the statistics level of 1%. The interaction of nitrogen fertilizer and Nitroxin biofertilizer on the length of the main stem and the number of branch at the 5% level, and the other traits were significant at the statistics level of 1% (*Table 1*).

Nitrogen increased coriander vegetative growth, compared to controls (*Table 2*). Application of 150 kg N·ha^{-1} significantly increased the main stem diameter, number of lateral branches, longest Internode length and shoot dry weight, compared with the control group and 75 kg N·ha^{-1}, respectively. Values of 75 and 100 kg N similarly increased the main stem length were compared to control (*Table 2*).

Table 1 - The results of analysis of variance effect of nitrogen fertilizers and Nitroxin on vegetative growth characteristics of coriander

Sources of change	d. f.	Mean square				
		Main stem length	Main stem diameter	Number of lateral branches	Longest internode length	Shoot dry weight
Block	2	10.767^{ns}	0.001 ^{ns}	0.271 ^{ns}	0.074 ns	21405.040^{ns}
Nitrogen	2	534.293**	0.147**	26.343**	67.737**	1729722.104**
Nitroxin	2	741.847*	0.080**	34.471**	39.310**	960038.884**
Nitrogen × Nitroxin	4	20.683*	0.005**	1.444*	5.181**	82539.277**
Error	16	6.784	0.001	0.553	0.958	12995.579

*, ** and ns, respectively indicate significant at the statistics levels of 5%, 1% and no significant difference.

Table 2 - Effect of different levels of nitrogen on vegetative growth characteristics of coriander

Nitrogen (kg·ha^{-1})	Main stem length (cm)	Main stem diameter (cm)	Number of lateral branches	Longest internode length	Shoot dry weight
0	40.8b	0.34c	8c	6.9c	1416.3c
75	53.5a	0.56b	10b	10.7b	1850.8b
150	54.7a	0.60a	11.4a	12.3a	2293.1a

In each column, means with the same letters are not significantly different at the 5% level statistically.

Table 3 - Effect of different levels of Nitroxin on vegetative growth characteristics of coriander

Nitroxin	Main stem length (cm)	Main stem diameter (cm)	Number of lateral branches	Longest internode length (cm)	Shoot dry weight (kg·ha^{-1})
0	39.2b	0.40c	7.6b	7.6c	1496.8c
2	9/53.9a	0.52b	10.5a	10.6b	1925.2b
4	8/55.8a	0.59a	11.3a	11.7a	2138.1a

In each column, means with the same letters are not significantly different at the 5% level statistically.

The application of Nitroxin biofertilizer determined significant increase of coriander vegetative characteristics, compared with control, so that the application of 4 L·ha^{-1} of Nitroxin increased average growth characteristics, compared to controls (*Table 3*). Except length of the main stem and the number of lateral branches, the application of 2 and 4 L·ha^{-1} of Nitroxin have the similar effects of other growth factors.

Combined use of nitrogen and Nitroxin fertilizer causes significant increase in vegetative growth of coriander, compared with individual use of these fertilizers (*Table 4*). The results of *Table 5* show that in all evaluated traits, except the length of the main stem and length of highest internode, the maximum means were observed when 150 kg N·ha^{-1} with 4 L·ha^{-1} of Nitroxin were combined together, however there were no any significant differences between treatments when 150 kg N·ha^{-1} combined with 2 or 4 L·ha^{-1} of Nitroxin. Also, in the two traits of the length of the main stem and number of lateral branches, when using Nitroxin, significant differences was not observed between levels of 75 and 150 kg N·ha^{-1} (*Table 4*).

At each level of nitrogen fertilizer, Nitroxin application leads to significant increase of growth characteristics and, in most cases, significant difference was not observed between the use of 2 and 4 L·ha^{-1} Nitroxin.

Table 4 - Effect of different levels of nitrogen and Nitroxin on vegetative growth characteristics of coriander

Nitrogen (kg·ha^{-1})	Nitroxin (L·ha^{-1})	Main stem length (cm)	Stem diameter (cm)	Number of lateral branches	Length of highest internodes	Final biomass
0	0	33.40d	0.28f	6.63c	5.9d	1107.72e
	2	43.40b	0.35e	8.13b	7.1cd	1489.30d
	4	45.50b	0.41d	9.20b	7.8cd	1651.80cd
75	0	40.06c	0.48c	7.26bc	7.1cd	1655.43cd
	2	59.10a	0.58b	10.96ab	11.1b	1833.70bc
	4	61.26a	0.63b	11.83a	13.8a	2063.16b
150	0	44.16b	0.45c	8.83b	9.9bc	1727.33c
	2	59.20a	0.62b	12.56a	13.6a	2452.53a
	4	60.63a	0.74a	12.76a	13.4ab	2699.30a

In each column, means with the same letters are not significantly different at the 5% level statistically.

Effect of nitrogen fertilizer and Nitroxin biofertilizer on yield, yield components and essential oil content of coriander

The effects of nitrogen fertilizer and Nitroxin and their interaction on all traits of yield, yield components and essential oil content of coriander was significant (*Table 5*). Nitrogen on all traits had a significant effect (p<0.01), except the essential oil content. Effect of Nitroxin on the

umbels number per plant was significant at the statistic levels of 5% and the other traits at the one percent level. Nitroxin and nitrogen interaction on the number of seeds per umbel at 5% and the other traits were significant at the statistics levels of 1%.

Table 5 - The results of analysis of variance effect of nitrogen fertilizers and Nitroxin on yield, yield components and essential oil content of coriander

Sources of change	d.f.	Mean square					
		Umbels number/ plant	Number of seeds/ umbel	Number of seeds/plant	Weight of 1000-seed	Grain yield ($kg \cdot ha^{-1}$)	Essential oil content
Block	2	1.751^{ns}	22.090^{ns}	83.054^{ns}	0.444^{ns}	7070.899^{ns}	32409.941^{ns}
Nitrogen	2	23.373**	348.969**	128999.420**	32.601**	1751098.058**	515706.906*
Nitroxin	2	24.835*	145.407**	96353.499**	18.573**	1237597.525**	273687.951**
Nitrogen × Nitroxin	4	2.571**	31.920*	6380.973**	2.312**	152938.761**	37374.570**
Error	16	0.387	16.722	2432.099	0.433	22967.646	9050.030

*, ** and ns, respectively indicate significant at the 5%, 1% and no significant difference.

Table 6 - Effect of different levels of nitrogen on yield, yield component and essential oil content of coriander

Nitrogen ($kg \cdot ha^{-1}$)	Umbels number/ plant	Number of seeds /umbel	Number of seeds /plant	1000-seed weight (g)	Grain yield ($kg \cdot ha^{-1}$)	Essential oil content ($kg \cdot ha^{-1}$)
0	9.8b	37.0b	309.4b	8.6b	594.4c	33.2c
75	10.0b	40.6b	352.1b	11.6a	942.7b	65.1b
150	12.7a	49.2a	534.8a	12.1a	1470.5a	92.0a

In each column, means with the same letters are not significantly different at the 5% level statistically.

Nitrogen increased the yield component, yield and essential oil content of coriander seeds (*Table 6*). The effect of 75 kg $N \cdot ha^{-1}$ on the number of umbels per plant, number of seeds per umbel and seed number per plant was statistically similar to the non application of nitrogen fertilizer. But the exception of 1000-seed weight, there was a significant difference in the other characters between application of 150 kg $N \cdot ha^{-1}$ and control and the application of 75 kg $N \cdot ha^{-1}$. The application of 150 kg $N \cdot ha^{-1}$ increased the number of umbels per plant, seeds per umbel, seed, 1000 seed weight, seed yield and essential oil content, 29.6, 33, 72.9, 40.7, 147.4 and 177.1%, when compared with the control, respectively, but no significant differences were observed between the two levels of nitrogen. The maximum grain yield (1470.5 $kg \cdot ha^{-1}$) and essential oil content (92 $kg \cdot ha^{-1}$)

was obtained with the application of 150 kg N·ha^{-1} (*Table 6*).

In the presence of Nitroxin biofertilizer yield, yield components and coriander essential oil content were increased significantly, compared to without Nitroxin conditions (control) and the maximum means of yield characteristics obtained with application 4 L·ha^{-1} of Nitroxin. The number of seeds per plant, seed yield and essential oil content, was more affected by Nitroxin than other traits were assessed, so that in the presence of 4 L·ha^{-1} of Nitroxin, number of umbel per plant, number of seeds per umbel, seed number per plant, 1000-seed weight, seed yield and essential oil content increased 35.9, 20.9, 64.7, 30.8, 88.9 and 83.9, in comparison with the control, respectively (*Table 7*). On the other hand, in all traits evaluated, with the exception of seed number per umbel and 1000-grain weight, there was no significant difference between two levels of Nitroxin. Nitroxin biofertilizer significantly cause to increase of coriander essential oil content (*Table 7*).

Table 7 - Mean comparison of different levels of Nitroxin on yield, yield component and essential oil content of medicinal plant of coriander

Nitroxin (L·ha^{-1})	Umbels number/ plant	Number of seeds/ umbel	Number of seeds/ plant	1000-seed weight (g)	Grain yield (kg·ha^{-1})	Essential oil content (kg·ha^{-1})
0	9.2c	38.2b	302.6c	9.1b	720.4c	43.5c
2	10.8b	42.5a	395.4b	11.3a	1026.2b	66.9b
4	12.5a	46.2a	498.4a	11.9a	1360.9a	80.08a

In each column, means with the same letters are not significantly different at the 5% level statistically.

The results in *Table 8* show the effect of different levels of nitrogen and Nitroxin on yield and essential oil content of coriander. The lowest average of traits was observed in terms of without application of biofertilizer and nitrogen (control). Nitroxin application increased the average of evaluating traits and at each level of nitrogen fertilizer with increasing in the amount of Nitroxin biofertilizer, the average of trait increased. On the other hand, for significant increase of the average of traits, compared with the control, it was necessary to apply simultaneously Nitroxin and nitrogen fertilizer, so that Nitroxin application alone did not increase significantly in all traits, except number of umbel per plant, compared to the control (*Table 8*).

With application of 150 kg N·ha^{-1}, the effect of Nitroxin on traits was the maximum, so that the maximum yield and yield component of coriander obtained with concurrent use of 150 kg N·ha^{-1} and 4 L Nitroxin per hectare and in most cases (with the exception of seed number per

umbel) this treatment has not significant differences with combined application of 150 kg N·ha^{-1} and 2 L·ha^{-1} of Nitroxin. Also, the maximum essential oil content was obtained in the treatment of 150 kg N·ha^{-1} with 2 or 4 L·ha^{-1} of Nitroxin (*Table 8*).

Table 8 - Mean comparison of different levels of Nitroxin and nitrogen on yield, yield component and essential oil content of medicinal plant of coriander

Nitrogen (kg·ha^{-1})	Nitroxin (L·ha^{-1})	Umbels number/ plant	Number of seeds/ umbel	Number of seeds/ plant	Weight of 1000 seed (g)	Grain yield (kg·ha^{-1})	Essential oil content (kg·ha^{-1})
0	0	8.86d	35.30e	265.1ef	8c	473.89d	23.65e
	2	9.33c	38.93de	306.8ef	8.7bc	593.76d	31.90e
	4	11.33b	36.90e	356.4de	9bc	715.51cd	44.18de
75	0	7.33e	36.13e	225.7f	9.6b	483.84d	33.53e
	2	9.96c	40.43cde	342.3de	11.9a	909.29c	72.26cd
	4	12.63ab	45.33bc	488.3bc	13.2a	1434.95b	81.55bc
150	0	11.36b	43.10bcd	416.9cd	9.7b	903.48c	73.44bcd
	2	13.16a	48b	537ab	13.2a	1575.67a	136.51a
	4	13.63a	56.40a	650.5a	13.4a	1932.28a	106.19ab

In each column, means with the same letters are not significantly different at the 5% level statistically.

DISCUSSION

Nitrogen fertilizer caused significantly improvement of vegetative growth characteristics of coriander. Maximum means of these traits was obtained with 150 kg N·ha^{-1}. Similar this result, Gujar *et al*. (2005) and Rahimi *et al*., (2009) showed that nitrogen fertilizer can improve vegetative features of coriander. This can be because of the role of nitrogen in stimulating cell growth, chlorophyll synthesis and amino acids, resulting in increased vegetative growth (Abd El-Wahab, 2007).

In our study, Nitroxin biofertilizer increased vegetative characteristics significantly when compared to control. The results of various studies show a positive impact of the use of biofertilizers, such Nitroxin on vegetative characteristics of coriander. So that similar our study, Nitroxin application stimulates growth factors of coriander, such as fresh and dry weight of plant and biomass (Shirkhodaei *et al*., 2014), plant height, number of lateral branches and plant dry weight (Rahimi *et al*., 2009), main stem length and biomass (Darzi *et al*., 2012), when compared with the control. It seems that Nitroxin by stimulating the absorption of nitrogen by plant roots (Mahfouz and Sharaf Eldin 2007; Kalyanasundaram *et al*., 2008), plant hormones production or through production of enzymes involved in plant development (Lucy *et al.,* 2004; Gray and Smith, 2005) determine increase in plant height, number of

leaves and therefore coriander biomass. Unlike these results, Jahanshahi *et al*. (2012) showed that the application of Nitroxin biofertilizer could not significantly increase in dry weight and number of branches in the cilantro.

Combined application of Nitroxin and nitrogen increased vegetative characteristics, significantly when compared with each individual application. Similar this result, some studies have shown that concurrent use of nitrogen fertilizers with organic fertilizers such Nitroxin, increase nitrogen use efficiency and thus lead to increased growth of medicinal plants (Mahfouz and Sharaf-Eldin 2007; Daneshvar *et al*., 2014). In a study that conducted by Rahimi *et al*. (2009), application of Nitroxin in coriander plants lead to reduce of consumption of nitrogen fertilizer by 50% and integrated treatment Nitroxin with 37.5 kg $N \cdot ha^{-1}$, similarly lead to increase growth characteristics of coriander by a single application of 75 kg $N \cdot ha^{-1}$ significantly. Hosseinpur *et al*. (2012) demonstrated that the most positive impact on growth characteristics of medicinal plant anise (*Pimpinella anisum* L.) is obtained with the integrated application of 6 $L \cdot ha^{-1}$ of Nitroxin with 60 $kg \cdot ha^{-1}$ of nitrogen fertilizer. *Azospirillum* and *Azotobacter* addition to nitrogen fixation ability, with the production of growth stimulants cause increased uptake of inorganic nitrogen and the growth (Tilak *et al*., 2005). Moreover, *Azotobacter* able to produce antifungal compounds against plant diseases that this issue leads to improved germination and seedling vigor, increase the absorption of nutrients and ultimately increase plant growth (Chen, 2006).

Nitrogen application, increased yield and yield component of coriander significantly, when compared to control. When 150 kg $N \cdot ha^{-1}$ was used, all of yield component and essential oil content, exception weight of 1000-seeds, increased significantly, compared with 75 kg $N \cdot ha^{-1}$. Similar these results, Gujar *et al*. (2005) stated that the highest yield of coriander was obtained with the application of 100 kg $N \cdot ha^{-1}$. It seems that nitrogen fertilizer application in the coriander plant increases the number of umbels per plant (Arganosa *et al*., 1998; Bist *et al*., 2000; Kumar *et al*., 2002; Rahimi *et al*., 2009), number of seeds per umbel and seed weight (Bist *et al*., 2000; Arganosa *et al*., 1998) and as a result, increases yield and essential oil, compared to the control. While in contrast to these results, Akbarinia *et al*. (2006) reported that although 60 kg $N \cdot ha^{-1}$ will increase the yield of coriander, but with the use of higher amounts, yield of seed decreases, while most of the essential oils obtained with the application of 90 kg $N \cdot ha^{-1}$. Nitrogen, because of its role in the biosynthesis of chlorophyll, amino acids, nucleic acids and enzymes, to enhance the growth and development in coriander (Abd El Wahab, 2007). Also, with increasing nitrogen in rhizosphere environment, investment products of photosynthesis in leaves

and stems increased, that this leads to stimulation of building materials and finally, their accumulation in seeds (Akbarinia *et al*., 2006).

The results of this study showed a positive effect of Nitroxin fertilizer on yield, yield components and essential oil content of coriander. Darzi *et al*. (2012) also reported that coriander seed inoculation with bacteria available in Nitroxin biofertilizer (*Azotobacter* or *Azospirillum brasilense*) increased the number of umbels per plant and seed yield, compared with the control. In studies that carried out by Shirkhodaei *et al*. (2014) and Kumar *et al*. (2002), the application of Nitroxin lead to improved growth and yield of coriander. In the study that conducted by Daneshvar *et al*. (2014), Nitroxin biofertilizer increased seed yield of fennel, compared to control. As well the application of Nitroxin fertilizer lead to increase the number of umbel per plant, seed per umbel and seed yield of fennel (Talaei *et al*., 2014) and seed yield. It seems that Nitroxin lead to produce and release the growth stimulants that they cause increased uptake of inorganic nitrogen and therefore growth and essential oil content of medicinal plants (Talaei *et al*., 2014).

Our study indicated a synergistic effect of Nitroxin and nitrogen fertilizer on yield and essential oil content coriander. The combined use of Nitroxin and nitrogen lead to increase of grain yield by increasing the number of umbels per plant, number of seeds per umbel and plant height (Talaei *et al*. 2014) and by increasing the synthesis of secondary metabolites (Daneshvar *et al*., 2014) increased the yield of coriander essential oil content. Nitroxin fertilizer improves the activity of nitrogen fixing bacteria, stimulates the absorption of nitrogen in the soil and resulting in increase of growth and yield of plant (Tilak *et al*., 2005; Sharma, 2002). Biofertilizers, by stimulating the uptake of nitrogen in the soil, increases the synthesis of secondary metabolites and thus increase the amount of essential oil content in the medicinal plant (Ozguven *et al*., 2006; Ashraf *et al*., 2006; Makkizadeh *et al*., 2011).

The use of biofertilizers, such as Nitroxin, by increasing soil organic matter, improve soil microbial activity and also increase absorption of nutrients, increases the rate of photosynthesis and dry matter of plant and consequently leads to improvement flowering and a number of umbels and resulting increase in seed yield of coriander (Salem and Awad 2005). The findings of Kumar *et al*. (2002) on coriander is also confirmed this topic. On the other hand, the application of *Azotobacter* by increasing the number of umbels per plant increased seed yield of fennel (Badran and Safwat, 2004).

Nitroxin application increase the amount of essential oil in the medicinal plants. It is reported that the use of biofertilizers Nitroxin increased the amount of seed essential oil of coriander (Darzi *et al*., 2012; Rahimi *et al*., 2009; Kumar, 2002), the herb

anise (Hosseinpur *et al*., 2012), chamomile (Fallahi *et al*., 2009), dill (Makkizadeh *et al*., 2011) and fennel (Daneshvar *et al*., 2014). Because essential oils are often terpenoides compounds and biosynthesis of their structural units (isoprenoides) is needy of ATP and NADPH and according to this topic that the presence of nitrogen is necessary for the formation of these compounds (Loomis and Corteau 1972). Therefore, the application of Nitroxin biofertilizer have the role in increase of environmental nitrogen, therefore Nitroxin lead to an increase in the oil of coriander.

CONCLUSION

The results showed that the combined use of nitrogen fertilizer and Nitroxin biofertilizer (*Azotobacter* and *Azospirillum*) by stimulating the absorption of nitrogen, promote plant hormones production or through production of enzymes involved in plant development can improve the growth characteristics, including the main stem length, the main stem diameter, number of lateral branches lead to the increase of the final biomass and therefore yield, yield components and essential oil content of coriander. Nitrogen application or Nitroxin alone could not significantly increase these traits, in comparison with the control. In most cases, the highest mean of above characteristics was obtained with the application of 150 kg $N \cdot ha^{-1}$ and 4 $L \cdot ha^{-1}$ of Nitroxin. Although application of nitrogen fertilizers, including urea, increased shoot growth and thus the yield of coriander, but in the rhizosphere, *Azotobacter* and *Azospirillum*, that are present in Nitroxin biofertilizer, stimulates plant growth through the synthesis and secretion of biologically active substances such as growth hormone (auxin and gibberellin), B vitamins, organic acids and biotin.

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