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Effect of Mineral vs. Biofertilizer on the Growth, Yield and Essential Oil Content of Coriander (*Coriandrum sativum* L.)

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ABSTRACT

In order to study the influence of nitrogen and biofertilizer on the growth, yield, and essential oil content of coriander (*Coriandrum sativum* L.), an experiment was conducted in 2007 at the experimental field of Gorgan University, Iran. Treatments were control (T1), biofertilizer (*Azotobacter* + *Azospirillum*) (T2), biofertilizer + 37.5 kg N (T3), and 75 kg N without inoculation (T4). Application of T4 and T3 significantly increased plant height, number of branches/plant, total dry weights, fruit yield, essential oil (EO) percentage, EO yield/plant, content of linalool in EO and linalool yield compared with control. The highest values were always obtained by T3 for all traits, followed by T4, but there were no significant differences in most cases. The lowest values were obtained in the control.

Keywords: *Azospirillum*, *Azotobacter*, linalool, nitrogen, nitroxin, yield

INTRODUCTION

Coriander (*Coriandrum sativum* L.), an annual herb of the parsley family (Umbelliferae) and native to the Mediterranean region has been cultivated since human antiquity (Telci *et al*. 2006). The seeds contain essential oil (EO) and linalool is the main component (Omidbaigi 2005). Coriander is economically important since it has been used as a flavouring agent in food products, perfumes and cosmetics. Coriander seeds are popular as spice and finely ground seed is a major ingredient of curry powder. The seeds are mainly responsible for the plant's medicinal use and have been used as a drug for indigestion, against worms, rheumatism and pain in the joints (Wangensteen *et al*. 2004). Moreover, the EO and various extracts from it have been shown to possess antibacterial (Burt 2004; Cantore *et al*. 2004; Kubo *et al*. 2004), antioxidant (Wangensteen *et al*. 2004) antidiabetic (Gallagher *et al*. 2003), anticancerous and antimutagenic (Chithra and Leelamma 2000) activities. EO accumulation in the plant is affected by several factors such as environmental conditions (Piccaglia and Marotti 1993; Fuente *et al*. 2003), genetic structure (Diederichsen 1996), cultural practices (Kaya *et al*. 2000) and fertilizer application (Alvarez-Castellanos and Pascual-Villalobos 2003; Gharib *et al*. 2008).

Nitrogen (N) fertilizer is a major input to arable and horticultural systems. For most arable and horticultural crops, an adequate supply of N is the main key to yield. It is the main component of plant amino acids, nucleic acid and chlorophyll, and is usually acquired by plants in greater quantity from the soil than any other element. N is the most widely used fertilizer nutrient and its consumption has increased substantially in recent decades (Pathak *et al*. 2006). Groundwater pollution caused by nitrates has risen dramatically throughout Europe and various attempts have been made to address and mitigate this problem (Davies 2000). Therefore, farmers should improve their management practices for optimised effectiveness of applied N, and application of environment-friendly techniques.

Organic products, based on philosophical preference and conviction or in response to an increasing market opportunity, exclude or prohibit the use of conventional crop inputs common to modern farming (Khalid *et al*. 2006). Synthetic pesticides and fertilizers are not appropriate in organic certification programs. To achieve optimal quality and economic returns, an organic farming system relies upon crop rotation, crop residues, animal manures, legumes, green manures, off farm organic wastes, and biological pest control. These components maintain soil productivity, supply nutrients and help control insects, weeds, and other pests (Khalid *et al*. 2006). In recent years, biofertilizers have emerged as a promising component of integrating nutrient supply system in agriculture. The organisms, such as mycorrhizal fungi and N-fixing bacteria, often participate with roots in the acquisition of nutrients (Taize and Zeiger 2002). Free-living N-fixing bacteria, such as *Azotobacter chroococcum* and *Azospirillum lipoferum*, were found to have not only the ability to fix N but also the ability to release phytohormones similar to gibberellic acid and indole acetic acid, which could stimulate plant growth, absorption of nutrients, and photosynthesis (Fayez *et al.* 1985; Mahfouz and Sharaf-Eldin 2007). Using biofertilizers that contain different microbial strains has led to a decrease in the use of chemical fertilizers and has provided high quality products free of harmful agrochemicals for human safety (Mahfouz and Sharaf-Eldin 2007).

The aim of this study was to determine the effect of mineral vs. biofertilizer on growth, yield, and EO content of coriander.

MATERIALS AND METHODS

A field experiment was conducted at the Gorgan University of Agriculture Sciences and Natural Resources, Research Farm, Gorgan (36°51'N, 54°16'E and 13 m ASL) during the 2007growing season. The experiment was laid out in randomized block design with three replications. Seeds were sown at a 25 cm row distance and 5 cm into row plots, consisting of nine rows 3 m long (2.5 m × 3 m = 7.5 m^2) on April 9, 2007. The main weather information, during 2007, and location 6 soil properties are given in **Tables 1**

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Short Communication

Table 1 Soil characteristics of the experimental field.

Soil texture	Available K (ppm)	Available P (ppm)	Organic (%) carbon	Naturalized (%) materials	pH	Electrical conductivity	Saturation point
Silty clay loam	186	11.3	0.84	2.25	7.9	0.6	51.5

Table 2 Climactic data of coriander growth season in 2007.

Month	Minimum temperature Mean (°C)	Maximum temperature Mean (°C)	Humidity mean (%)	Monthly rainfall (mm)	Sunshine hours (hours/day)
May	13	22.8	74.4	29.9	12.7
June	18.7	32.1	56.1	17.9	13
July	22.1	31	68.25	10.6	12
August	22.9	35.2	56.4	13.3	12.8

Table 3 Effect of nitrogen and biofertilizers on growth and fruit yield of coriander (*Coriandrum sativum* L)

Treatments	Plant height (cm)	Number of branches	Number of umbels	Plant dry weight (g)	Fruit yield plant^{-1} (g)
Control	51.76 b	10.52 b	59.78 b	5.08 c	5.72 b
Biofertilizer	57.30 ab	11.17 b	72.12 ab	5.79 bc	6.50 ab
Biofertilizer+50%N	62.93 a	12.37 a	85.87 a	6.81 a	6.99 a
100%N	60.22 a	12.13 a	80.30 a	6.39 ab	6.72 a
LSD (5%)	6.18	0.77	14.67	0.75	0.87

T1 (control without treatment), T2 (*Azotobacter* and *Azospirillum*), T3 (*Azotobacter* and *Azospirillum* + 50% N), and T4 (100% N without inoculation). Means with the same letter are not significantly different.

and **2**, respectively. Irrigation was carried out regularly when soil moisture content was lower than field capacity. The plots were kept weed-free by hand.

Treatments were control (T1), biofertilizer (T2), biofertilizer + 37.5 kg N (T3), and 75 kg N without inoculation (T4). N fertilizer (75 kg/ha) determined according to soil testing. Then 1/3 N was applied as a basal dose at sowing time and the remaining N was applied after thinning and shooting phase. Nitroxin (*Azotobacter* + *Azospirillum*) was used as biofertilizer (provided by Mehr Asia Biotechnology Co., Iran). Coriander seeds (3 kg) were inoculated with 0.5 l nitroxin before sowing.

Plant height, number of branches, number of umbels, biomass (g/plant), fruit yield (after air drying; g/plant), EO yield and linalool yield were measured at the final stage of maturity (i.e. brown fruits).

EO was isolated by a Clevenger-type apparatus according to Marotti and Piccaglia (1992). EO yield (ml/plant) was calculated by multiplying EO percentage and fruit yield. To obtain the linalool content of EO the samples was analyzed by HPLC. The HPLC system, equipped with a dual pump model L-7100 Lachrom (Merck HITACHI), UV Detector model L-7400 Lachrom (Merck HITACHI) and column, C18 (250 × 4.6 mm, 5 µm particle size). Acetonitrile (50%) was the mobile phase and the analysis was done at 210 nm with a 1 ml/min flow rate. Different doses of linalool (50–400 ppm) were injected into the HPLC to determine peak retention time relative to linalool and to establish a standard curve. Then, 600 ppm of EO (6 µl EO + 10 ml acetonitrile) of each sample was injected into the HPLC and the linalool content in samples was determined according to the standard curve. Linalool yield (mg/plant) was calculated by multiplying the linalool content per EO and EO yield. Data were analyzed using SAS software and the mean values were compared using the LSD test at 5%.

RESULTS AND DISCUSSION

Growth and yield

All growth parameters and yield characters such as plant height, number of branches, number of umbels, dry weight of plant and fruit yield were increased by the application of N fertilizer alone and significantly so by biofertilizer + 37.5 kg/ha N (**Table 3**). Biofertilizer also increased these parameters but there was no significant difference between biofertilizer and control. The highest values of growth parameters were obtained by application of biofertilizer + 37.5 kg/ha N.

These results are in agreement with those obtained by Amin (1997), who showed that inoculation of *C. sativum*, *Foeniculum vulgare* and *Carum carvi* by *Azotobacter* and *Azospirillum* with a half dose of inorganic fertilizer resulted in improved growth. Mahfouz and Sharaf-Eldin (2007) found that the application of *Azotobacter chroococcum*, *Azospirillum liboferu* and *Bacillus megatherium* increased vegetative growth, fruit yield, uptake nutrient and total carbohydrates compared to chemical fertilizer treatments in *F. vulgare*. Kandeel *et al*. (2002) reported that inoculation of *Ocimum basilicum* with symbiotic N_2-fixers (*Azotobacter* + *Azospirillum*) supplemented with a half or full dose of inorganic-N fertilizer significantly increased growth parameters and yearly EO yield/plot compared with control treatment (given 100 kgN/fedd). Kumar *et al*. (2002) noted that seed inoculation of coriander with *Azotobacter* and *Azospirillum* either singly or in combination enhanced seed and stover yields, harvest index and total N uptake rather than no inoculation treatment.

The enhanced growth and yield of *C. sativum* plants in the present work could be attributed to the importance of N as they participate in chlorophyll building. So, the pigment content in leaves was enhanced, which may be reflected more in photosynthesis; moreover, N is also important for amino acid building and protein synthesis in addition to nucleic acids and enzymes, all these metabolites are needed for plant growth and development (Abd El-Wahab 2007). *Azotobacter* and *Azospirillum* play important roles in N fixation. In addition, they provide growth-promoting substances such as indole acetic acid, gibberellins and cytokinins (Barea and Brown 1974; Pareek *et al*. 1996; Zahir *et al*. 1997), or indirectly change the microflora of the rhizosphere (Barea and Brown 1974).

Essential oil yield

Data in **Table 4** shows that the application of bio- and mineral fertilizers increased the EO percentage, but only the effect of T3 (biofertilizer + 37.5 kg/ha N) was significantly higher than the control. The highest (0.64%) and lowest (0.58%) EO percentages were obtained by a mixture of biofertilizer + N and control, respectively. These results agree with those obtained by Kandeel *et al*. (2002) for *Ocimum basilicum*, who found that the highest percentage of EO resulted from inoculating the plants with *Azotobacter* + *Azospirilium* in the presence of a full or half dose of N.

Results in **Table 4** also indicate that all treatments significantly increased the EO yield per plant compared to the control. The highest EO yield per plant (0.045 ml/plant) was obtained in the mixture of biofertilizer + 37.5 kg/ha N. EO yield was influenced by both EO percentage and fruit yield. Mahfouz and Sharaf-Eldin (2007) reported that a mixture of biofertilizer + 50% NPK had a greater effect on increasing the EO yield in *F. vulgare*.

Table 4 Effect of nitrogen and biofertilizers on content of essential oil and linalool of coriander (*Coriandrum sativum* L).

Treatments	Essential oil percentage	Essential oil yield/plant (ml/plant)	Linalool content (mg/1ml oil)	Linalool yield (mg/plant)
Control	0.58 b	0.033 b	499.39 b	16.49 c
Biofertilizer	0.62 ab	0.040 a	508.10 b	20.33 b
Biofertilizer+50%N	0.64 a	0.045 a	544.31 a	24.51 a
100%N	0.61 ab	0.041 a	542.50 a	22.25 ab
LSD (5%)	0.04	0.005	18.33	3.14

T1 (control without treatment), T2 (*Azotobacter* and *Azospirillum*), T3 (*Azotobacter* and *Azospirillum* + 50% N), and T4 (100% N without inoculation). Means with the same letter are not significantly different.

Inoculating coriander seeds with biofertilizer + 37.5 kg/ha N and treatment of 75 kg/ha N increased the content of linalool in EO significantly (**Table 4**). The highest level of linalool (544.31 mg/l ml EO) was obtained from the mixture of biofertilizer + 37.5 kg/ha N. Application of biofertilizer alone also increased the linalool content in the EO, but was not significantly different to the control. These results are similar to those of Mahfouz and Sharaf-Eldin (2007) for *F. vulgare*; they showed that application of each of *Azotobacter*, *Azospirillum* and *Bacillus* with 50% NPK alone or as a mixture increased the linalool content in EO of fennel; a mixture of all biofertilizers with chemical fertilizer was greatest. Application of bio- and chemical fertilizer alone or mixed together significantly improved the linalool yield per plant with respect to control (**Table 4**).

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