



Original Article

# Effects of Vermicompost and Nitrogen Fixing Bacteria on the Concentration and Composition of Essential Oil in Coriander (*Coriandrum sativum* L.)

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## ABSTRACT

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To evaluate the effects of vermicompost and nitrogen-fixing bacteria on the concentration and composition of coriander essential oil, we conducted a  $4 \times 2$  factorial field trial arranged in a randomized complete block design with three replicates in Firouzkuh, Iran (2021). Treatments were vermicompost at 0, 3, 6, and 9 t ha<sup>-1</sup> and seed inoculation with a mixture of *Azotobacter chroococcum* and *Azospirillum lipoferum* (non-inoculated vs. inoculated). Vermicompost significantly affected all measured traits except linalool percentage. The 6 t ha<sup>-1</sup> rate maximized essential-oil content (0.536%), essential-oil yield (17.6 kg ha<sup>-1</sup>), and  $\alpha$ -pinene percentage, while it minimized cymene percentage. Seed inoculation increased essential-oil yield but did not significantly alter oil content or the relative abundances of linalool,  $\alpha$ -pinene, or cymene. The 6 t ha<sup>-1</sup> vermicompost  $\times$  inoculation combination further enhanced  $\alpha$ -pinene percentage. Overall, moderate vermicompost application—with or without inoculation—can improve coriander essential-oil production while favorably shifting its monoterpene profile.

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## 1. Introduction

The use of organic amendments and biofertilizers, including vermicompost and nitrogen-fixing bacteria such as *Azotobacter* and *Azospirillum*, has attracted increasing attention as a sustainable alternative to chemical fertilizers. These inputs can reduce reliance on synthetic fertilizers while enhancing the quality of agricultural products (Migahed et al., 2004; Mahfouz & Sharaf Eldin, 2007). Appropriate nutrient management through organic and biofertilizers can maximize both the quantity and quality of bioactive compounds in medicinal plants (Anwar et al., 2005; Singh et al., 2009).

Coriander (*Coriandrum sativum* L.), native to the Mediterranean and Middle Eastern regions, is widely valued for its aromatic fruits. The distinctive aroma and flavor are attributed to essential oils stored in the oil glands of the mericarp, with linalool typically representing the major component (up to 70–80% of the oil). Coriander fruits are used in cooking, baking, and the flavoring of alcoholic and non-alcoholic beverages, as well as in the production of soaps and pharmaceuticals. The essential oil also serves as a carminative and flavoring agent in traditional medicine (Diederichsen,

1996; Msaada et al., 2009; Burdock & Carabin, 2009; Matasyoh et al., 2009).

Previous studies have shown that vermicompost can enhance essential-oil content and quality in several medicinal and aromatic plants, including basil (Singh & Ramesh, 2002; Anwar et al., 2005; Geetha et al., 2009), coriander (Singh et al., 2009), fennel (Darzi et al., 2009; Moradi et al., 2011), chamomile (Haj Seyed Hadi et al., 2011), cumin (Saeid Nejad & Rezvani Moghaddam, 2011), dill (Darzi et al., 2012), and anise (Darzi et al., 2013). Similarly, biofertilizers based on nitrogen-fixing bacteria (*Azotobacter chroococcum* and *Azospirillum lipoferum*) have been reported to increase both yield and essential-oil quality in crops such as fennel (Abdou et al., 2004; Mahfouz & Sharaf Eldin, 2007; Azzaz et al., 2009; Moradi et al., 2011), lemon balm (Harshavardhan et al., 2007), turmeric (Velmurugan et al., 2008), hyssop (Koocheki et al., 2009), cumin (Saeid Nejad & Rezvani Moghaddam, 2010), black cumin (Valadabadi & Farahani, 2011), and dill (Darzi et al., 2012).

Given these findings, the present study was designed to investigate the interactive effects of vermicompost and nitrogen-fixing bacteria on both the quantity and quality



of essential oil in coriander. This work aims to provide insights into the potential of integrating organic and biological fertilization strategies to enhance essential-oil

## 2. Materials and Methods

### 2.1. Field Experiment

A  $4 \times 2$  factorial experiment was conducted in a randomized complete block design with three replications at the Experimental Farm of the Agriculture Company of Ran, Firouzkuh, Iran, during the 2021 growing season. The site is located at  $35^{\circ}45' N$ ,  $52^{\circ}44' E$ , at an altitude of 1930 m. Treatments included four levels of vermicompost (0, 3, 6, and  $9 \text{ t ha}^{-1}$ ) and two levels of seed inoculation with a bacterial mixture of *Azotobacter chroococcum* and *Azospirillum lipoferum* (non-inoculated vs. inoculated). Seed inoculation was performed by immersing coriander seeds in a bacterial suspension ( $10^8 \text{ CFU ml}^{-1}$ ) for 15 min.

Vermicompost was produced from animal manure using the epigeic earthworm *Eisenia foetida*. The required quantities were incorporated into the top 5 cm of soil before sowing. Soil samples (0–30 cm depth) were collected prior to land preparation for physicochemical analysis. Selected soil and vermicompost properties are presented in Tables 1 and 2.

Each plot measured  $3 \times 2 \text{ m}$  with plant spacing of 10 cm within rows and 40 cm between rows. One-meter alleys separated plots, and two meters separated replications. Coriander seeds were directly sown by hand. During the experiment, no serious pest or disease incidence was observed. Weeding was done manually, and drip irrigation was applied weekly. All other agronomic practices and plant protection measures were applied uniformly across treatments.

From each plot, 20 plants were randomly sampled for data collection. Quantitative and qualitative traits measured included essential-oil content, essential-oil yield, and relative percentages of linalool,  $\alpha$ -pinene, and cymene.

### 2.2. Extraction of Essential oil

To determine essential-oil content (%), 100 g of coriander seeds from each plot were ground, mixed with 500 ml distilled water, and subjected to hydro-distillation for 3 h using a Clevenger-type apparatus (Kapoor et al., 2004; Darzi et al., 2012). Essential-oil yield ( $\text{kg ha}^{-1}$ ) was calculated from essential-oil content and seed yield.

### 2.3. Identification of Essential oil Components

Essential-oil fractions were analyzed using gas chromatography (GC) and gas chromatography–mass spectrometry (GC/MS). GC analysis was performed on a Younglin Acm600 equipped with an HP-5 MS capillary column ( $30 \text{ m} \times 0.25 \mu\text{m}$ ). GC/MS analysis was carried out with an Agilent 6890 GC and an Agilent 5973 MS,

both equipped with an HP-5 MS capillary column ( $30 \text{ m} \times 0.25 \mu\text{m}$ ). Authentic standards of linalool,  $\alpha$ -pinene, and cymene were used to confirm retention times (Sephidkon, 2002; Kapoor et al., 2004).

**Table 1.** Some Traits of Physical and Chemical of soil in experiment site

K	P	N	O.C	EC	pH	Texture
(mg/kg)	(mg/kg)	(%)	(%)	(ds/m)		
720	48	0.127	1.86	1.55	7.6	Clay-Loamy

**Table 2.** Some Characteristics of Chemical of used Vermicompost

K	P	N	O.C	O.M	EC	pH
(%)	(%)	(%)	(%)	(%)	(ds/m)	
3.9	0.67	11.3	26.1	45	1.8	8.5

### 2.4. Statistical Analysis

All data were subjected to analysis of variance (ANOVA) using SAS software (version 9.1). Treatment means were compared with Duncan's Multiple Range Test (DMRT) at a 5% probability level. Data transformations were applied as necessary to satisfy assumptions of normality of residuals.

## 3. Results

### 3.1. Essential oil content

Essential-oil content was significantly influenced by vermicompost levels (Figure 1). The highest value (0.536%) was obtained at  $6 \text{ t ha}^{-1}$  vermicompost. Neither inoculation with nitrogen-fixing bacteria nor the interaction between factors significantly affected essential-oil content (Table 3).

### 3.2. Essential oil yield

Vermicompost application also significantly increased essential-oil yield (Figure 2). The maximum yield ( $17.6 \text{ kg ha}^{-1}$ ) was observed at  $6 \text{ t ha}^{-1}$  vermicompost. Seed inoculation had a significant positive effect, with inoculated seeds producing  $13.8 \text{ kg ha}^{-1}$  compared with  $11.4 \text{ kg ha}^{-1}$  for non-inoculated seeds (Table 3).

### 3.3. Linalool percent in essential oil

Linalool percentage, the dominant constituent of coriander oil, was not significantly affected by vermicompost or biofertilizer (Figure 3; Table 3). Mean values ranged from 75.4% to 76.3% across treatments.

### 3.4. Alpha pinene percent in essential oil

Vermicompost application significantly influenced  $\alpha$ -pinene content (Figure 4). The highest percentage (5.40%) occurred at  $6 \text{ t ha}^{-1}$  vermicompost. Although biofertilizer alone had no significant effect, the

interaction between vermicompost and inoculation was significant. The maximum  $\alpha$ -pinene percentage (5.90%) was achieved with 6 t ha<sup>-1</sup> vermicompost combined with inoculation.

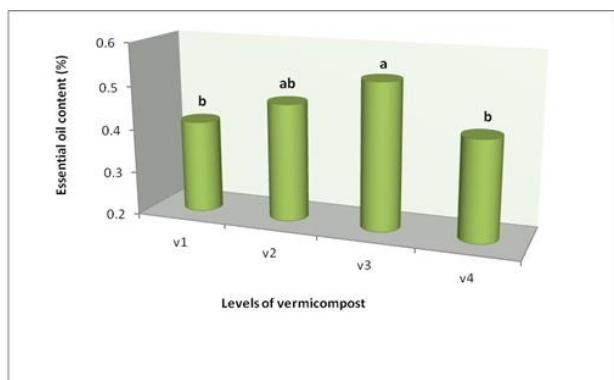
### 3.5. Cymene percent in essential oil

Cymene percentage was significantly reduced by vermicompost application (Figure 5). The lowest value (4.21%) was recorded at 6 t ha<sup>-1</sup> vermicompost. Biofertilizer did not significantly affect cymene levels (Table 3).

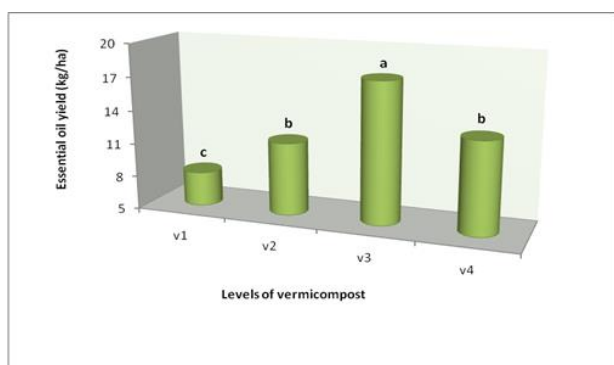
**Table 3.** Mean comparison of coriander essential oil traits at different levels of nitrogen-fixing bacteria

Treatments	Essential oil content (%)	Essential oil yield (kg ha <sup>-1</sup> )	Linalool percent in essential oil (%)	Alpha pinene percent in essential oil (%)	Cymene percent in essential oil (%)
b1	0.444 a	11.42 b	76.29 a	4.76 a	4.58 a
b2	0.481 a	13.84 a	75.43 a	4.87 a	4.70 a

Means within a column followed by the same letter are not significantly different at the 5% probability level (DMRT). b1 = non-inoculated; b2 = inoculated with Azotobacter + Azospirillum.



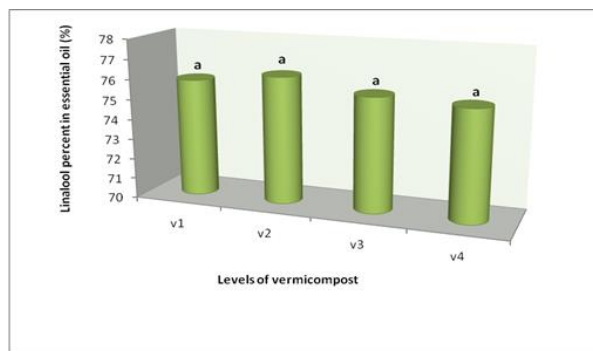
**Fig 1.** Essential oil content of coriander at different vermicompost levels (v1 = 0, v2 = 3, v3 = 6, v4 = 9 t ha<sup>-1</sup>).



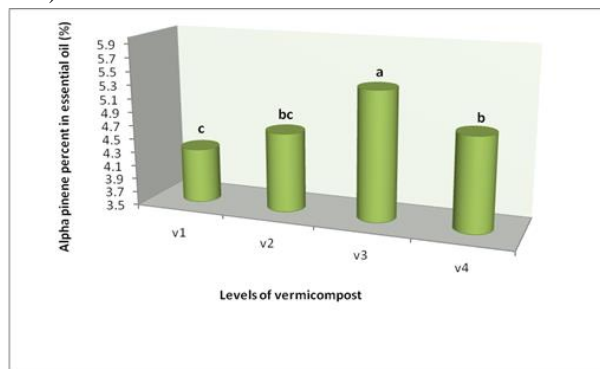
**Fig 2.** Essential oil yield of coriander at different vermicompost levels (v1 = 0, v2 = 3, v3 = 6, v4 = 9 t ha<sup>-1</sup>).

## 4. Discussion

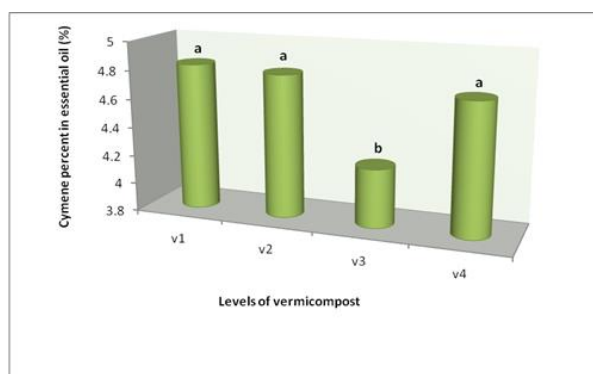
Application of vermicompost enhanced mineral nutrient availability, particularly nitrogen and phosphorus,



**Fig 3.** Linalool percentage in essential oil of coriander at different vermicompost levels (v1 = 0, v2 = 3, v3 = 6, v4 = 9 t ha<sup>-1</sup>).



**Fig 4.**  $\alpha$ -Pinene percentage in essential oil of coriander at different vermicompost levels (v1 = 0, v2 = 3, v3 = 6, v4 = 9 t ha<sup>-1</sup>).



**Fig 5.** Cymene percentage in essential oil of coriander at different vermicompost levels (v1 = 0, v2 = 3, v3 = 6, v4 = 9 t ha<sup>-1</sup>).

through improved soil biological activity, which in turn increased biomass production and essential-oil accumulation. Similar positive effects of vermicompost on essential-oil yield and composition have been documented in other medicinal and aromatic plants, including basil, fennel, chamomile, and dill (Anwar et al., 2005; Darzi et al., 2009; Geetha et al., 2009; Singh et al., 2009; Haj Seyed Hadi et al., 2011; Darzi et al., 2012). Our findings corroborate these reports, showing that optimal vermicompost application (6 t ha<sup>-1</sup>) improved essential-oil content and yield in coriander.

The observed increase in essential-oil yield can be attributed to enhancements in both essential-oil content and seed yield. These results are consistent with earlier

studies that highlighted the role of vermicompost in boosting yield components and oil productivity (Singh & Ramesh, 2002; Pandey, 2005; Saeid Nejad & Rezvani Moghaddam, 2011; Moradi et al., 2011). In addition, biofertilizer inoculation improved essential-oil yield, supporting evidence that nitrogen-fixing bacteria promote plant growth and secondary metabolism (Abdou et al., 2004; Mahfouz & Sharaf Eldin, 2007; Koocheki et al., 2009; Kumar et al., 2009; Valadabadi & Farahani, 2011).

The increase in  $\alpha$ -pinene percentage observed with vermicompost application may be due to enhanced metabolic activity and nutrient assimilation, which favor biosynthesis of specific monoterpenes. These findings agree with reports in basil, fennel, and dill, where vermicompost increased desirable monoterpenes while decreasing less favorable constituents such as cymene (Anwar et al., 2005; Darzi et al., 2009; Moradi et al., 2011; Darzi et al., 2012). Our study also demonstrated that the interaction between vermicompost and biofertilizer further boosted  $\alpha$ -pinene levels, consistent with earlier evidence of synergistic effects between organic amendments and biofertilizers (Harshavardhan et al., 2007; Padmapriya & Chezhiyan, 2009).

In contrast, cymene percentage decreased with vermicompost addition. This shift in oil composition suggests that vermicompost not only increases oil yield but also favors the accumulation of more desirable compounds (e.g.,  $\alpha$ -pinene) at the expense of others (e.g., cymene). Such qualitative modifications have been previously reported in medicinal plants under integrated nutrient management (Anwar et al., 2005; Darzi et al., 2009; Moradi et al., 2011).

Overall, the present findings emphasize the dual role of vermicompost and biofertilizers in enhancing both the quantity and quality of coriander essential oil. By improving soil fertility, stimulating microbial activity, and modulating secondary metabolism, these inputs can serve as effective, sustainable tools in the production of high-quality essential oils.

## 5. Conclusion

Manure and foliar The results of this study demonstrate that both vermicompost and nitrogen-fixing bacteria can significantly enhance coriander essential-oil production. Application of vermicompost at 6 t ha<sup>-1</sup> proved optimal, maximizing essential-oil content, yield, and  $\alpha$ -pinene percentage while reducing cymene percentage. Seed inoculation with *Azotobacter* and *Azospirillum* further increased essential-oil yield, and when combined with vermicompost, it enhanced oil quality through higher  $\alpha$ -pinene accumulation.

These findings suggest that integrated use of organic and biological fertilizers provides a sustainable strategy for

improving both the quantity and quality of essential oil in coriander. Such practices reduce reliance on chemical fertilizers, improve soil fertility, and support environmentally friendly production systems. Future research should focus on long-term field evaluations and scaling these practices for broader adoption in medicinal and aromatic plant cultivation.

## References

- Abdou, M.A.H., El Sayed, A.A., Badran, F.S. & El Deen, R.M.S. (2004). Effect of planting density and chemical and biofertilization on vegetative growth, yield and chemical composition of fennel (*Foeniculum vulgare* Miller): I - Effect of planting density and some chemical (Nofatrein) and biochemical (Biogen) fertilizers. *Annals of Agricultural Science*. 42(4), 1907-1922.
- Anwar, M., Patra, D.D., Chand, S., Alpesh, K., Naqvi, A.A. & Khanuja, S.P.S. (2005). Effect of organic manures and inorganic fertilizer on growth, herb and oil yield, nutrient accumulation, and oil quality of French basil. *Communications in Soil Science and Plant Analysis*. 36 (13-14), 1737-1746.
- Arancon, N.Q., Edwards, C.A., Lee, S. & Byrne, R. (2006). Effects of humic acids from vermicomposts on plant growth. *European Journal of Soil Biology*. 42, s65-s69.
- Azzaz, N.A., Hassan, E.A. & Hamad, E.H. (2009). The chemical constituent and vegetative and yielding characteristics of fennel plants treated with organic and bio-fertilizer instead of mineral fertilizer. *Australian Journal of Basic and Applied Science*. 3(2), 579-587.
- Burdock, G.A. & Carabin, I.G. (2009). Safety assessment of coriander (*Coriandrum sativum* L.) essential oil as a food ingredient. *Food and Chemical Toxicology*. 47,22-34.
- Darzi, M.T., Ghalavand, A., Sefidkon, F. & Rejali, F. (2009). Effects of Mycorrhiza, Vermicompost and Phosphatic Biofertilizer Application on Quantity and Quality of Essential Oil in Fennel (*Foeniculum vulgare* Mill.). *Iranian Journal of Medicinal and Aromatic Plants*. 24(4), 396-413.
- Darzi, M.T., Haj Seyed Hadi, M.R. & Rejali, F. (2012). Effects of the application of vermicompost and nitrogen fixing bacteria on quantity and quality of the essential oil in dill (*Anethum graveolens*). *Journal of Medicinal Plants Research*. 6(21), 3793-3799.
- Darzi, M.T., Hadj Seyed Hadi, M.R. & Rejali, F. (2013). Effects of Vermicompost and Phosphatic Biofertilizer Application on Quantity and Quality of Essential Oil in Anise. *Iranian Journal of Medicinal and Aromatic Plants*. 29(3), 583-594.
- Diederichsen, A. (1996). Coriander: promoting the conservation and use of underutilized and neglected

- crops. International Plant Genetic Resources Institute, Rome, Italy.
- Geetha, A., Rao, P.V., Reddy, D.V. & Mohammad, S. (2009). Effect of organic and inorganic fertilizers on macro and micro nutrient uptake, oil content, quality and herbage yield in sweet basil (*Ocimum basilicum*). *Research on Crops*. 10(3), 740-742.
- Haj Seyed Hadi, M.R., Darzi, M.T., Ghandehari, Z. & Riazi, G.H. (2011). Effects of vermicompost and amino acids on the flower yield and essential oil production from *Matricaria chamomile* L. *Journal of Medicinal Plants Research*. 5(23), 5611-5617.
- Harshavardhan, P.G., Vasundhara, M., Shetty, G.R., Nataraja, A., Sreeramu, B.S., Gowda, M.C. & Sreenivasappa, K.N. (2007). Influence of spacing and integrated nutrient management on yield and quality of essential oil in lemon balm (*Melissa officinalis* L.). *Biomedicines*. 2(3), 288-292.
- Jat, R.S., & Ahlawat, I.P.S. (2006). Direct and residual effect of vermicompost, biofertilizers and phosphorus on soil nutrient dynamics and productivity of chickpea-fodder maize sequence. *Journal of Sustainable Agriculture*. 28, 41-54.
- Kapoor, R., Giri, B. & Mukerji, K.G. (2004). Improved growth and essential oil yield and quality in *Foeniculum vulgare* Mill on mycorrhizal inoculation supplemented with P-fertilizer. *Bioresource Technology*. 93, 307-311.
- Koocheki, A., Tabrizi, L. & Ghorbani, R. (2009). Effect of biofertilizers on agronomic and quality criteria of Hyssop (*Hyssopus officinalis*). *Iranian Journal of Agronomy Research*. 6(1), 127-137.
- Kumar, T.S., Swaminathan, V. & Kumar, S. (2009). Influence of nitrogen, phosphorus and biofertilizers on growth, yield and essential oil constituents in ratoon crop of davana (*Artemisia pallens* Wall.). *Electronic Journal of Environment, Agriculture and Food Chemistry*. 8(2), 86-95.
- Mahfouz, S.A. & Sharaf Eldin, M.A. (2007). Effect of mineral vs. biofertilizer on growth, yield, and essential oil content of fennel (*Foeniculum vulgare* Mill.). *International Agrophysics*. 21(4), 361-366.
- Matasyoh, J.C., Maiyo, Z.C., Ngure, R.M. & Chepkorir, R. (2009). Chemical composition and antimicrobial activity of the essential oil of *Coriandrum sativum*. *Food Chemistry*. 113, 526-529.
- Migahed, H.A., Ahmed, A.E. & Abdel Ghany, B.F. (2004). Effect of different bacterial strains as biofertilizer agents on growth, production and oil of *Apium graveolens* under calcareous soil. *Arab Universities Journal of Agricultural Science*. 12(2), 511-525.
- Moradi, R., Nasiri Mahallati, M., Rezvani Moghaddam, P., Lakzian, A. & Nejad Ali, A. (2011). The effect of application of organic and biological fertilizers on quantity and quality of essential oil in fennel (*Foeniculum vulgare*). *Journal of Horticultural Science*. 25(1), 25-33.
- Msaada, K., Ben Taarit, M., Hosni, K., Hammami, M. & Marzouk, B. (2009). Regional and maturational effects on essential oils yields and composition of coriander (*Coriandrum sativum* L.) fruits. *Scientia Horticulturae*. 122, 116-124.
- Padmapriya, S. & Chezhiyan, N. (2009). Effect of shade, organic, inorganic and biofertilizers on morphology, yield and quality of turmeric. *Indian Journal of Horticulture*. 66(3), 333-339.
- Pandey, R. (2005). Mangement of *Meloidogyne incognita* in *Artemisia pallens* with bio-organics. *Phytoparasitica*. 33(3), 304-308.
- Saeid Nejad, A.H. & Rezvani Moghaddam, P. (2010). Evaluation of biofertilizer and chemical fertilizer application on morphological traits, yield, yield components and essential oil percent in cumin (*Cuminum cyminum*). *Journal of Horticultural Science*. 24(1), 38-44.
- Saeid Nejad, A.H. & Rezvani Moghaddam, P. (2011). Evaluation of compost, vermicompost and cattle manure application on yield, yield components and essential oil percent in cumin (*Cuminum cyminum*). *Journal of Horticultural Science*. 24(2), 142-148.
- Sephidkon, F. (2002). Evaluation of Quantitative and Qualitative of fennel (*Foeniculum vulgare*) essential oil in different growth stages. *Iranian Journal of Medicinal and Aromatic Plants*. 7, 85-104.
- Singh, M. & Ramesh, S. (2002). Response of sweet basil (*Ocimum basilicum*) to organic and inorganic fertilizer in semi-arid tropical conditions. *Journal of Medicinal and Aromatic Plant Science*. 24(4), 947-950.
- Singh, B., Singh, B., Masih, M.R. & Choudhari, R.L. (2009). Evaluation of P and S enriched organic manures and their effect on seed yield and quality of coriander (*Coriandrum sativum*). *International Journal of Agricultural Science*. 5(1), 18-20.
- Swaminathan, V., Kumar, T.S., Sadasakthi, A. & Balasubramanian, R. (2008). Effect of nitrogen and phosphorus along with biofertilizers on growth, yield and physiological characteristics of Davana (*Artemisia pallens* Wall.). *Advances in Plant Science*. 21(2), 693-695.
- Valadabadi, S.A., Farahani, H.A. (2011). Investigation of biofertilizers influence on quantity and quality characteristics in *Nigella sativa* L. *Journal of Horticulture and Forestry*. 3(3), 88-92.
- Velmurugan, M., Chezhiyan, N. & Jawaharlal, M. (2008). Influence of organic manures and inorganic fertilizers on cured rhizome yield and quality of turmeric (*Curcuma longa* L.) cv. BSR-2. *International Journal of Agricultural Science*. 4(1), 142-145.

Zaller, J.G. (2007). Vermicompost as a substitute for peat in potting media: Effects on germination, biomass allocation, yields and fruit quality of three tomato varieties. *Scientia Horticulture*. 112, 191-199.