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Original Article

Composition of essential oil in coriander (*Coriandrum sativum* L.) as influenced by manure and amino acid application

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ABSTRACT

The main objective of this investigation was to study the effects of manure and amino acid foliar application on the quantity and quality of essential oil in coriander. The experiment was conducted at the research fields of Islamic Azad University, Roudehen, Iran in the spring of 2017. The experiment was carried out as a factorial arrangement based on a randomized complete block design with three replications. The factors were manure application at five levels (0, 3, 6, 9, and 12 ton ha^{-1}) and amino acid foliar application at two levels (control and foliar application). Results showed that the highest essential oil content (0.56%) and geranyl acetate (2.61%) were obtained by using 12 ton ha^{-1} of manure. But, applying 9 ton ha^{-1} of manure resulted in maximum alpha-pinene (10.83%) and linalool (69.93 %). Mean comparison showed that amino acid foliar application caused maximum essential oil content (0.5%), alpha-pinene (10.35%), and linalool (68.20%). Gamma-terpinene and orto-cimene content in essential oil were significantly affected by the interaction of treatments so that the maximum gamma-terpinene (10.16%) was obtained by using 6 ton ha^{-1} of manure with amino acid foliar application whereas the highest orto-cimene content (1.58%) was observed by using 9 ton ha^{-1} of manure with amino acid foliar application. Overall, the results of this experiment show that manure and foliar application of amino acid play an important role in improving the quality of the essential oil of coriander in a sustainable production system.

1. Introduction

Sustainable and organic production systems have been developed for improving the biological processes and ecological balance in the world cropping systems, and one of their principles is the application of organic fertilizers and bio-stimulants in cropping ecosystems in order to eliminate or reduce the use of chemical inputs (Haj Seyed Hadi & Rezaee Ghale, 2016). In some cases, organic fertilizers can be applied as an alternative and in most cases as a supplement to chemical fertilizers to ensure the sustainability of agricultural systems (Shaalan, 2005). This leads to increased plant yield, particularly in medicinal plants, by improving soil bioactivity and supplying nutrients for the plants (Rao, 2001). Application of manure increases the number of small pores (30 µm in diameter), especially in soils characterized by a coarse texture, which increase water penetration rate, hydraulic conductivity and soil water holding capacity (Rezaei, 2013). Other studies have pointed to the positive effect of manure on improving soil physical structure and increasing soil water absorption and retention (Ramesh et al., 2009). Positive effects of manure on medicinal plants include increase in biomass and essential oil content in common sage (*Salvia officinalis*) (Kaplan et al., 2009), increase in essential oil in black seed (*Nigella sativa*) (Ghanepasand et al., 2014), yarrow (*Achillea millefolium*) (Scheffer et al., 1993), dill (*Anethum graveolens*) (Khalid & Shafei, 2005), Moldavian dragonhead (*Dracocephalum moldavica* L.) (Darzi et al., 2016), coriander (*Coriandrum sativum* L.) (Bastami et al., 2016) and peppermint (*Mentha piperita* L.) (Asadi et al., 2019). The results of various studies also indicate the improvement of essential oil composition in medicinal plants due to the application of manure. In this regard, increasing alpha-pinene in coriander (Darzi & Haj Seyed Hadi, 2014), significant increase in the amount of myrcene, cumin aldehyde and paracetamol in cumin (*Cuminum cyminum* L.) (Ahmadian et al., 2006), increase in neral percentage, geranium and geranyl percentage in Moldavian dragonhead (Darzi et al., 2016) and an increase in geranyl acetate in coriander (Yari & Tab, 2018) have been reported. Amino acids also act as stimulants of quantitative and qualitative

plant growth. These compounds play an important role in biosynthesis of secondary and hormonal metabolites (Gawronak, 2008). In general, amino acids are substances that stimulate metabolism and metabolic processes and enhance plant performance (Faten et al., 2010). Therefore, the use of bio-stimulants can be one of the most important factors in successful cultivation of a medicinal plant because they affect the quantitative as well as qualitative traits of the herb (Haj Seyed Hadi et al., 2016). This effect caused by application of amino acids in formulation of bio-stimulants will lead to the improvement of quantitative and qualitative characteristics in a shorter time, especially under environmental stresses, by increasing the mRNA replication up to 2.5 times, activating hormones effective on reproductive growth, activating carbohydrates formation process, increasing absorption and transport of elements and increasing protein content in plants (Gawronak, 2008; Thomas et al., 2009).

The positive effects of amino acids on plants include improving the biochemical composition of tea (Thomas et al., 2009), and increasing the quantitative and qualitative yield of chamomile (*Matricaria recutita*) (Golzadeh et al., 2011).

Coriander (*Coriandrum sativum* L.) is an annual plant with seeds containing about one percent of essential oil. The aromatic smell of this plant is related to the aldehyde present in its essential oil (Deng et al., 2003). Essential oil of coriander fruit is used in the pharmaceutical and cosmetic industries and its fruit oil is also used in food and pharmaceutical industries (Sefidkon, 1999). It is also consumed as a food digester, anti-flatulence, appetizer, muscle pain reliever and sedative (Demir, 2004).

Considering the importance of sustainable agriculture development and application of medicinal plants as natural medications containing no problematic compounds for human health, this investigation aimed at studying the effects of manure and amino acid foliar application on the quantity and quality of essential oil in coriander.

2. Materials and Methods

This investigation was conducted in the spring 2017 in the research farm of Raan Agriculture and Animal Husbandry Company, 10 km far from Firouzkooh city, with a longitude of 52° 44´ E and a latitude of 35° 45´ N, at an altitude of 1930 m above sea level.

Before conducting the research, sampling was done from different parts of the field soil at a depth of 0-30 cm; after mixing the samples, it was transferred to the laboratory to characterize the physical and chemical properties, and the results are presented in Table 1.

Table 1. Physical and chemical properties of the soil of experiment site.

Soil Texture	Acidity (pH)	Electrical Conductivity (dS m^{-1})	Organic Carbon (%)	Organic Matter (%)	Total Nitrogen (%)	Phosphorous (mg kg^{-1})	Potassium (mg kg^{-1})
Silt Loam	7.6	1.55	0.81	1.39	0.06	10	300

The experiment was carried out in factorial arrangement based on randomized complete block design in three replications. The factors were manure application at five levels (0, 3, 6, 9 and 12 ton ha^{-1}) and amino acid foliar application at two levels (non-foliar application and foliar application). Amounts of manure was determined and applied considering the net nitrogen requirement of coriander (90 kg ha^{-1}) (Akbarinia et al., 2006; Salem & Awad, 2005), percentage of nitrogen in manure (2.56%) (Table 2) and the release of 35% of nutrients from organic sources in the first year (Rezaei, 2013). The manure was applied to the relevant plots according to the experimental plan, spread over the furrows created on the ridges, and entirely mixed (Rezvani Moghadam et al., 2013). The physical and chemical status of cow manure used in this study is presented in Table 2.

Table 2. Physical and chemical properties of the manure applied in experiment.

Acidity (pH)	Electrical Conductivity (dS m^{-1})	Organic Carbon (%)	Organic Matter (%)	Total Nitrogen (%)	Phosphorous (mg kg^{-1})	Potassium (mg kg^{-1})
7.2	1.22	34.5	59.6	2.56	0.82	0.41

Humiforte was mixed at a ratio of 25 cc in 5 l of water and sprayed on the plants. Foliar application of this commercial compound was carried out in the early morning in the absence of wind and according to the experimental plan. The compounds in Humiforte are listed in Table 3.

Table 3. Different amino acids and their respective amounts in Humiforte.

Compound	Content (%)
Glycine	1.8
Valine	5.1
Proline	8.4
Alanine	13.21
Aspartic acid	4.5
Arginine	8.4
Glutamic acid	0.9
Lysine	5.1
Lectine	16.51
Isolectine	4.5
Phenilalanine	5.1
Methionine	4.2
Serine	3.9
Thereonine	3.0
Histidine	3.0
Glycerol	9.6
Tyrosine	1.5
Glutamine	0.9
Cystine	1.3

In the spring, upon seedbed preparation operations, seeds were planted.

Coriander seeds were supplied by the Medicinal plants and By-products Research Station of Esfahan Agriculture and Natural Resources Research Center. The seeds were sown on rows at a distance of 10 cm from each other and depth of 3 cm with between-row spacing of 40 cm (Bastami & Majidian, 2015).

Drip irrigation method was applied by using tape pipes. For uniform emergence of plants, two initial irrigations were performed with 3-d interval followed by the irrigation run every 5 days. At the two- to four-leaf stage, the plants were thinned to achieve the desired density (25 plants m^{-2}) (Bastami & Majidian, 2015). The manual weeding was carried out during the growing season to control weeds.

At the final harvest stage, taking into account the marginal effect, plants were harvested in an area of one square meter per plot and transferred to the laboratory. The measured traits were the percentage and components of essential oil.

The essential oil was extracted at Research Institute of Forests and Rangelands. For this purpose, 100 g of grain, after grinding, was heated in Clevenger for 4 hours. The extracted essential oil was dried by sodium sulfate and weighed (Bigonah et al., 2014).

The Gas Chromatography and Gas Chromatography by Mass Spectrometry (Novak et al, 2006) were employed to determine the components of the essential oil.

The statistical analysis of data obtained from the experiment was performed using SAS software. Duncan's multiple range tests was used to compare the means of treatments and Excel program was used to draw the graphs.

3. Results

3.1 Essential oil content

Application of manure and amino acid had a significant effect on the percentage of essential oil at 1% probability level (Table 4). The highest percentage of essential oil was obtained by applying 12 ton ha^{-1} manure, which shows a 75% increase compared to the control treatment (Table 5). The lowest percentage of essential oil (0.32%) was obtained in the treatment of non-application of manure (control). The means comparison for amino acid foliar application showed that the highest percentage of essential oil (0.50%) was obtained by amino acid foliar application whereas the lowest percentage (0.37%) was observed in non-application treatment (Table 6), where the results confirm an increase of 35.14 % in the seed essential oil content compared to the non-sprayed treatment.

3.2 Alpha-pinene content

The manure and amino acid applications had a significant effect, at 1% and 5% probability levels, respectively, on the amount of alpha-pinene in the essential oil but their interactions were not significant (Table 4). The means comparison for manure application treatment showed that the highest percentage of alpha-pinene (10.83%) was obtained by applying 9 ton ha^{-1} manure (Table 5), indicating an increase of 20.7% in the amount of alpha-pinene compared to the non-application treatment (control). Regarding the amino acid foliar application, the means comparison showed that the highest percentage of alpha-pinene (10.35%) was obtained with amino acid foliar application whereas the lowest percentage (9.92%) was obtained with non-foliar application. Foliar application of Humiforte led to a 4.3-percent increase in the alpha-pinene amount (Table 6).

Table 4. Results of variance analysis for essential oil percentage and its most important components in coriander (*Coriandrum sativum* L.) under manure and amino acids application.

Source of variation	df	Mean of squares (MS)					
		Essential oil percentage	Alpha-pinene	Orto-cimene	Gamma-Terpinene	Linalool	Geranyl acetate
Replication	2	0.0012	0.4714	0.0174	0.1476	0.0273	0.0384
Manure	4	0.0531**	2.9254**	0.1061**	0.6873**	0.3330**	1.5649**
Amino Acid	1	0.1267**	1.7083*	0.0326	0.0619	0.1921**	0.4687**
Manure × Amino Acid	4	0.0091	0.5017	0.0734*	0.8491**	0.0632	0.0278
Error	18	0.0036	0.2472	0.0123	0.0822	0.0220	0.0432
Coefficient of variation (%)		7.67	4.90	8.04	2.95	2.16	4.51

ns, * and ** indicate insignificant and the significant differences between traits at P-value<0.05 and P-value<0.01., respectively.

Table 5. Comparison of means for essential oil percentage properties and its most important components in coriander (*Coriandrum sativum* L.) under manure application.

Manure (t/ha)	Essential oil percentage	Alpha-pinene	Orto-cimene	Gamma-Terpinene	Linalool	Geranyl acetate
0	0.32 d	8.97 c	1.22 b	9.19 c	65.86 c	1.36 c
3	0.40 c	10.12 b	1.32 b	9.86 ab	68.18 ab	1.54 c
6	0.41 c	10.35 ab	1.32 b	9.36 b	65.41 c	1.51 c
9	0.49 b	10.83 a	1.55 a	9.84 ab	69.93 a	2.00 b
12	0.56 a	10.36 ab	1.47 a	10.08 a	67.97 b	2.61 a

Means followed by similar letters in each column do not significantly differ at α= 5% probability level based on LSD test.

Table 6. Comparison of means for essential oil percentage and its most important components in coriander (*Coriandrum sativum* L.) under amino acid foliar application.

Treatment	Essential oil percentage	Alpha-pinene	Orto-cimene	Gamma-Terpinene	Linalool	Geranyl acetate
Non-Foliar Application	0.37 b	9.92 b	1.34a	9.57a	66.42b	1.93a
Foliar Application	0.5 a	10.35a	1.41a	9.86a	68.20a	1.68b

3.3 Orto-cimene content

The manure application at 1% probability level and interaction of manure and amino acid applications at 5% probability level had a significant effect on orto-cimene content in the essential oil (Table 4). Applying 9 ton ha^{-1} manure together with Humiforte foliar application led to the highest amount of orto-cimene (1.58%) whereas the least amount of orto-cimene (1.18%) was found when no manure or amino acid foliar application had been applied (Fig. 1).

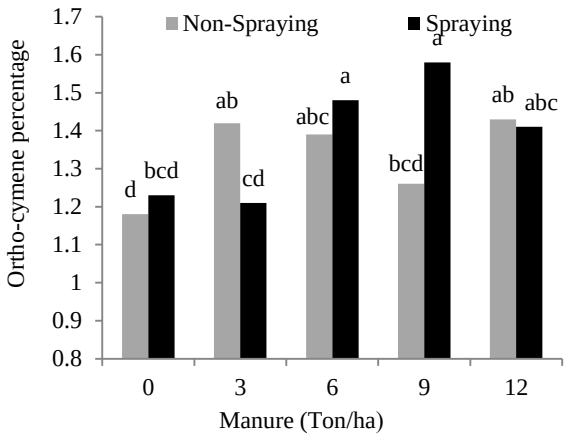

Fig. 1. Mean comparison for the interaction of Manure and amino acid spraying on Orto-cimene Percent.

3.4 Gamma-terpinene content

The manure application at 1%, and interaction of manure and amino acid applications at 1% probability level had a significant effect on gamma-terpinene content in the coriander essential oil (Table 4). Applying 6 ton ha^{-1} manure together with Humiforte foliar application led to the highest amount of gamma-terpinene (10.16%) in the coriander essential oil whereas the lowest amount (9.17%) was found when 3 t/ha manure along with amino acid foliar spraying had been applied (Fig. 2).

3.5 Linalool content

The manure and amino acid applications had a significant effect at 1% probability level on the amount of linalool, however, no significant effect was found for the interaction of the two factors (Table 4). The mean comparisons for manure indicated that the highest amount of linalool (69.93 %) was obtained by applying 9 ton ha^{-1} manure whereas the least amount of linalool (65.41 %) was observed by applying 6 ton ha^{-1} manure (Table 5). The mean comparison for amino acid indicated that the maximum amount of linalool (68.20) was obtained by Humiforte foliar application showing 2.7 % increase in linalool amount in coriander essential oil (Table 6).

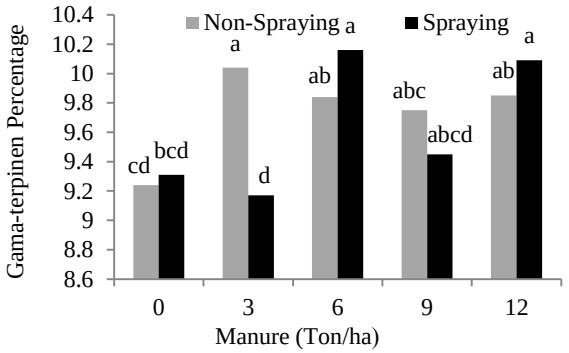

Fig. 2. Mean comparison for the interaction of manure and amino acid spraying on Gamma-Terpinene Percent.

3.6 Geranyl acetate content

The manure and the amino acid applications had a significant effect at 1% probability level on the amount of geranyl acetate; however, no significant effect was found for the interaction of the two factors (Table 4). The mean comparison for manure (Table 5) indicated that the highest geranyl acetate content (2.61 %) was yielded by applying 12 ton ha^{-1} manure whereas the least amount (1.36 %) was found when manure was not applied. The mean comparison for amino acid (Table 6) indicated that the maximum amount of geranyl acetate (1.93 %) was obtained by non-foliar application of Humiforte whereas by foliar application, geranyl acetate content in the coriander essential oil was reduced to 1.68 %.

4. Discussion

The results showed that the application of manure had a positive and significant effect on the percentage of coriander essential oil, which should be related to the supply of nitrogen and phosphorous by the manure.

Essential oils are terpenoid compounds and their constituent units (i.e. isoprenoids) such as isopentyl Pyrophosphate (IPP) and dimethylallyl pyrophosphate (DMAPP) essentially require NADPH and ATP, and elements such as nitrogen and phosphorous are crucial for formation of the above-mentioned compounds (Ghazi Manas et al., 2013); therefore, increasing the quantity of manure can lead to increased essential oil yield through enhancing the phosphorous and nitrogen uptake.

A study on dill indicated an increase in the essential oil yield obtained by applying 30 ton ha^{-1} manure (Khalid & Shafei, 2005). In another study, Ghanepasand and Haj Seyed Hadi (2016) by examining the effect of different amounts of manure on black seed showed that

the application of 7.5 ton ha^{-1} manure led to a significant increase in the percentage of black seed essential oil. Darzi et al. (2016) also showed that the highest percentage of essential oil was obtained in Moldavian dragonhead by applying 10 ton ha^{-1} manure. The results of other studies also show the positive effect of manure on the essential oil yield of common sage (Kaplan et al., 2009), coriander (Aghhavani Shajari et al., 2014; Bastami et al., 2016), peppermint (Asadi et al., 2019), and dill (Shahmohammadi et al., 2012). This is due to the improvement of soil qualitative properties and its water holding capacity under water scarcity, which in turn, increases the access to nutrients for production of photosynthetic materials and secondary metabolites (Mandal et al., 2007). However, the results of some studies indicate the negative effect of organic fertilizers on the percentage of essential oils of medicinal plants (Moradi et al., 2011), although, even in such cases, the positive effects of organic fertilizers on growth and soil structure cannot be ignored (Aghhavani Shajari et al., 2014).

Considering the positive effect of amino acids foliar application on minerals uptake and increase of plant nitrogen content, as well as the important and effective role of nitrogen in the formation of essential oil, it seems that a 35.14% increase in grain essential oil compared to the control can be justified. The results of Saburi et al. (2014) indicated the positive effect of Aminolforte and Humiforte foliar application on the percentage of basil essential oil. Another study investigated the effect of different amounts of vermi-compost, urea, and amino acids foliar application on quantitative and qualitative properties of chamomile. The results showed that Aminolforte foliar application increases the percentage of German chamomile essential oil (Haj Seyed Hadi & Rezaee Ghale, 2016).

Since amino acids are nitrogenous compounds, their application as foliar application in plants can provide more energy required for making terpenoid compounds, which ultimately leads to an indirect increase in the amount of essential oil produced by the plant (Alcázar et al., 2010; Shirzadi et al., 2014).

The results of this experiment showed that the amount of alpha-pinene in the essential oil was influenced by manure application so that with increase in the manure up to 9 ton ha^{-1}, an increasing and significant trend was observed in the amount of alpha-pinene and by applying 6, 9 and 12 ton ha^{-1} manure, 10.35, 10.83 and 10.36% of alpha-pinene were obtained, respectively, although no significant difference was observed between these treatments. Alpha-pinene levels increased due to improvement in soil biological activity and gradual uptake of water and nutrients, which in turn was resulted by applying the manure (Chatterjee, 2002; Eghball et al., 2002; Mohapatra & Das, 2009). The manure can improve the activity of beneficial bacteria and provide mineral solubility and access for the plant (Yari & Tab, 2018). The results of other studies also confirm the improvement of essential oil quality due to the application of manure. In their research, Darzi and Haj Seyed Hadi (2014) showed that the highest percentage of alpha-pinene (10.05%) was obtained in coriander by applying 10 ton ha^{-1} manure. These results are consistent with Khalid and Shafei (2005) study on coriander; however, Ahmadian et al. (2006) showed that the application of 20 ton ha^{-1} manure reduced the amount of alpha-pinene in cumin, and under the treatment where the manure was not applied, such traits were higher.

The orto-cimene amount in coriander essential oil was not influenced by the manure treatments and amino acid foliar application, but the interactions of the treatments had a significant effect on the amount of this trait. The highest rate of this trait (1.58%) was obtained in the combined treatment of 9 ton ha^{-1} manure and amino acids foliar application, which did not show a significant difference with the treatment of 6 t/ha manure and amino acids foliar application (1.48%). The lowest amount of orto-cimene was also obtained in the combined treatment of non-application of manure and amino acid. A study demonstrated that manure application increased the amount of thymol in *Trachyspermum* (Akbarinia et al., 2006). Also, in another study, the highest percentage of neral in Moldavian dragonhead was obtained by applying 10 ton ha^{-1} manure and the highest percentage of geraniol and geranial was obtained by using 10 ton ha^{-1} manure with 5 ton ha^{-1} vermicompost (Darzi et al., 2016).

Other studies have pointed to the positive and significant effect of foliar application of amino acids on the quality of essential oils. In this regard, Haj Seyed Hadi and Rezaee Ghale (2016) showed that foliar application of Aminol Forte, an amino acid, increased camazoline in chamomile. Ansarifar et al. (2012) and Golzadeh et al. (2012) found similar results on chamomile.

Gamma-terpinene was increased due to the improvement of beneficial microbial activities in the soil and the desirable provision of macro and microelements in coriander (Chatterjee, 2002). Darzi and Haj Seyed Hadi (2014) showed that the highest percentage of gamma-terpinene in coriander was obtained by applying 15 ton ha^{-1} manure. The studies have also shown that amino acids directly and indirectly affect the physiological activities of the plant and the crop quality (Faten et al., 2010) and this has been effective in improving the amount of gamma-terpinene in coriander essential oil. The above-mentioned cases indicate that the combined application of manure and amino acids has positively influenced the amount of

gamma-terpinene in coriander. However, Ahmadian et al. (2006) showed that the application of 20 t/ha manure reduced the amount of gamma-terpinene in cumin and the amount of this trait was higher when no manure was used. Also, Eblagh et al. (2013) stated that the highest percentage of gamma-terpinene and para-cimene in *Trachyspermum* belonged to the treatment of non-application of manure and the lowest percentage to the application of 30 ton ha^{-1} manure.

Our results showed that the highest amount of linalool in essential oil (69.93%) was obtained by applying 9 ton ha^{-1} manure, although no significant difference was observed between this treatment and the treatments of 3 and 12 ton ha^{-1} manure. With respect to the increase of linalool due to the application of manure, it can be argued that manure contains appropriate amounts of macro and microelements and improves the linalool content in the plant by gradual release of nutrients (Yari & Tab, 2018). In their study on the effect of organic fertilizers on coriander, Darzi and Haj Seyed Hadi (2014) showed that the highest percentage of linalool (73.96%) in essential oil was obtained by applying 10 ton ha^{-1} manure. These results are in accordance with the studies conducted by Osman (2009) on fennel and Ateia et al. (2009) on thyme, which indicates that the application of manure is effective in improving the quality of essential oils of medicinal plants.

Regarding the positive effect of amino acid foliar application on product quality, the results of studies have shown that foliar application of amino acids and bio-stimulants can improve the physiological parameters and biochemical composition of the tea plant (Thomas et al., 2009).

The highest amount of geranyl acetate (2.61%) was obtained by applying 12 ton ha^{-1} manure, which was significantly different from other treatments. Application of animal manure led to increased soil biological activity and absorption of mineral elements (Eghball et al., 2002; Mohapatra & Das, 2009), which in turn enhanced the plant growth and consequently increased geranyl acetate in essential oil. In this regard, Ateia et al. (2009) in their study on thyme observed that the combined application of 20 ton ha^{-1} manure and 10 ton ha^{-1} vermicompost significantly increased the percentage of thymol, which was attributed to the improvement of chemical and physical conditions of the soil.

It was also reported that the combined application of 9 ton ha^{-1} manure and nitrogen-fixing bio-fertilizer significantly increased the percentage of geraniol and neral in Moldavian dragonhead essential oil (Harshavardhan et al., 2007). Also, Padmapriya and Chezhiyan (2009) and Osman (2009) stated that application of organic fertilizers improves the absorption of macro and micro nutrients and enhances the quality of essential oils due to a significant increase in geraniol and geranyl acetate in turmeric and fennel, respectively. Darzi and Haj Seyed Hadi (2014) showed that the highest percentage of geranyl acetate (3.18 %) was obtained with 15 ton ha^{-1} manures application.

The amino acid foliar application could not cause a significant increase in the amount of geranyl acetate, so that the highest amount of this trait (1.93%) was obtained in non-spraying treatment.

In this experiment, the highest levels of components of coriander essential oil were obtained in different treatments and a specific treatment was not characterized as the best treatment for all traits. It is reasonable that an increase in one component of the essential oil is compensated for by reduction in another, and this has been also reported in other studies. A study by Yari and Tab (2018) showed that the highest content of geranyl acetate in coriander was obtained by applying 10 t ha^{-1} cow manure with 5 ton ha^{-1} vermi-compost, while the highest content of alpha-pinene and gamma-terpinene was obtained by using 10 ton ha^{-1} vermi-compost. In another study, Ahmadian et al. (2006) showed that the application of manure significantly increased the amount of essential oil and cumin aldehyde, para-cemine and myrcene indices in cumin, but the levels of alpha-pinene, beta-pinene and gamma-terpinene decreased by applying the manure. This is also confirmed by the results obtained on green basil (Asheghi et al., 2018) and coriander (Yari & Tab, 2018).

5. Conclusion

Manure and foliar application of amino acids had a positive and significant effect on the percentage of essential oil and some important compounds in coriander essential oil. The highest amounts of essential oil and geranyl acetate were obtained by applying 12 ton ha^{-1} manure whereas the highest amounts of alpha-pinene and linalool were obtained by using 9 ton ha^{-1}. The amounts of orto-cimene and gamma-terpinene were influenced by the interaction of the treatments, so that the highest amount of orto-cimene was produced by the combined application of 9 ton ha^{-1} manure and amino acids foliar application and the highest amount of gamma-terpinene was obtained by 6 ton ha^{-1} manure and amino acids foliar application. Overall, the manure application and amino acid foliar application could enhance the amount of essential oil and its quality in coriander, so that, they could be recommended in sustainable production systems of medicinal plants.

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