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Original Article

Effects of vermicompost and *Mycorrhizal* Fungi on organic production of summer savory (*Satureja hortensis* L.)

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ABSTRACT

To evaluate the characteristics of savory under vermicompost and mycorrhizae treatments, an experiment was conducted in 2021 on organic research lands located in Chenar-e Shargh, Damavand, in a factorial design within a Completely Randomized Block Design (CRBD). The factors in this experiment included different levels of vermicompost (0, 2.5, and 5 tons per hectare) and mycorrhizal fungi (non-utilization, *G. mosseae*, *G. intraradices*, and a combination of *G. intraradices* + *G. mosseae*). Results demonstrated that different levels of vermicompost and mycorrhizal fungi had significant effects on the studied traits. Among the vermicompost levels, the utilization of 5 tons per hectare of vermicompost resulted in the highest percentage of essential oil (1.25%) and the highest essential oil yield (23.71 kg ha^{-1}),. Additionally, among the levels of mycorrhizal fungi, the highest percentage of essential oil (1.28%) and essential oil yield (23.70 kg ha^{-1}) were achieved through the combination of *G. intraradices* and *G. mosseae* fungi. The application of *G. intraradices* and *G. mosseae* fungi resulted in an increase in the percentage of essential oil and essential oil yield compared to the control. The results of this study indicate that seed inoculation with mycorrhizal fungi and the use of vermicompost had the great positive impact on the quantity and quality of summer savory.

1. Introduction

Summer savory (*Satureja hortensis* L.) is an annual herbaceous plant belonging to the Lamiaceae family (Mumivand et al., 2013). Its distribution in Iran is primarily in the western regions of Azarbaijan and the north (Rechinger, 1982). The essential oil of summer savory finds application in industries such as canning and beverage production. It possesses antimicrobial properties, inhibiting the growth of certain bacteria (Hajhashemi et al., 2002). The essential oil of this plant contains numerous bioactive compounds that nowadays are extensively used in pharmaceutical and food industries.

In the production of medicinal plants, real value is attributed to the quality of the product and the stability of production, with the quantity of the product being of secondary importance. Studies conducted on medicinal plants in natural and agricultural ecosystems suggest that the use of sustainable agricultural systems provides the best conditions for the production of these plants due to their alignment with natural conditions and preservation of product quality (Darzi *et al*., 2009). Proper application of nutrients in the production of medicinal plants plays a crucial role not only in quantity but also in the quality of their active ingredients (Makkizadeh Tafti et al., 2012; Zare et al., 2013). The application of organic fertilizers in a sustainable agricultural system leads to the enhancement of both quantity and quality of active ingredients and increased yield in medicinal plants (Kapoor et al., 2004; Darzi et al., 2012).

The use of vermicompost in sustainable agriculture not only increases support and activity of beneficial soil microorganisms (such as mycorrhizal fungi and phosphate-solubilizing microorganisms) in providing essential plant nutrients such as nitrogen, phosphorus, and potassium in a soluble form but also improves the growth and yield of agricultural plants (Arancon et al., 2006).

In an experiment investigating the amounts of vermicompost (0%, 15%, and 30% volume of the pot) in Moldavian dragonhead (*Dracocephalum moldavica* L.), the highest amount of essential oil in the vegetative parts (0.74%) and the highest amount of geranyl acetate in the essential oil (61.1%) were obtained with the highest amount of vermicompost consumption (Mafakheri et al., 2012). The results of Ghazi Manas et al. (2013) demonstrate a significant and meaningful effect of different levels of vermicompost on the percentage and yield of essential oil. Vermicompost resulted in an increase in the amount of essential oil in the plant, with the highest amount of essential oil obtained from the treatment with 20 tons per hectare of vermicompost.

Mycorrhizae are fungi that colonize the roots of many agricultural plants. This symbiotic relationship is beneficial for both the fungus and the plant. Mycorrhizal fungi enhance the absorption of nutrients by host plants and can improve the growth, quality, and tolerance of plants to environmental stress factors (Azmat & Hamid, 2015). Mycorrhizal fungi increase the absorption of nutrients, especially phosphorus, thereby enhancing the growth and performance of plants (Yadav & Aggarwal, 2015; Elhag et al., 2015). Mycorrhizal fungi primarily provide nutrients, mainly phosphorus and other complex compounds, to plants through the extensive hyphal network. For this relationship to occur, suitable plant, appropriate ecological habitat, and compatible fungal strain must be present. These fungi have a limited spectrum of tolerance to environmental factors and exhibit specific adaptabilities to their growth substrate.

The aim of the present study is to evaluate the quantity and quality of the essential oil of medicinal plant savory using different levels of vermicompost and inoculation with mycorrhizal fungi in a sustainable production system.

2. Materials and Methods

This research was conducted in 2021 to evaluate the quantity and quality of the essential oil of the medicinal plant savory, using different levels of vermicompost and mycorrhizal fungi in a sustainable production system, in research lands located in Chenar-e Shargh village, Damavand. The experiment was conducted in a factorial design within a completely randomized block design with three replications. The treatments used in this study included three levels of vermicompost (no application, 2.5 and 5 tons per hectare) and four levels of mycorrhizal fungi (no application, *G. mosea*, *G. intradices*, and a combination of *G. intradices* and *G. mosea*).

The seeds of summer savory (*Satureja hortensis* L.) were obtained from the Medicinal Plants and Misalenous-Products Research Unit, Agricultural and Natural Resources Research Center of Isfahan Province. After plowing, discing, and creating planting furrows using a furrower, the treatments were applied. The mycorrhizal fungi were obtained from the Zist Fannavar-e-Touran Biotechnology Company located in Shahroud, and the vermicompost was sourced from the Anousheh Araab Company. The dimensions of the plots are 2.25 × 3 meters. A distance of 2 meters was maintained between replications, and there were two unplanted rows between adjacent plots. Each plot contains six planting rows with a spacing of 37.5 centimeters. The distance between the plants within each row is 10 centimeters. Prior to planting, soil samples were taken from a depth of 0 to 30 centimeters to determine pH, soil texture, and available nutrients (Haj Seyed Hadi & Darzi, 2018), and were transferred to the laboratory for physical and chemical analysis (Table 1). Additionally, a sample of vermicompost used in this study was also transferred to the laboratory for analysis, and its chemical status is presented in Table 2.

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

Soil Texture	Acidity (pH)	Electrical Conductivity (dS m^{-1})	Organic matter (%)	S.P %	Total Nitrogen (%)	Phosphorous (mg kg^{-1})	Potassium (mg kg^{-1})
Sandy-Clay Loam	8.0	1.31	2.29	41.78	0.04	37.9	480

Table 2. Physical and Chemical Characteristics of the Vermicompost Used in the Experiment

Total nitrogen %	Total phosphorus %	Total potassium %	Total copper %	Total zinc %	Total iron %	Total manganese %
1.10	0/65	0.51	0.002	0.01	0.22	0.02

Humidity %	Organic materials %	Organic carbon %	C/N %	pH	EC (dS/m)	K_2O %	P_2O_5 %
49.20	22.95	13.10	11/90	7.54	4.82	0.62	1.50

The soil preparation of the land involved plowing, discing, and harrowing in the spring of the year 2021. The vermicompost was applied to the designated plots according to the plot map, and it was spread over the furrows created on the beds. It was thoroughly mixed with the soil up to a depth of five centimeters on the beds (Rezvani Moghadam et al., 2014).

During the growth period, weeds present in the field were manually removed. In each experimental plot, a border row was considered along one side, and half a meter from both ends of each plot. The first irrigation was applied immediately after planting, and the second irrigation was repeated three days later to ensure rapid and uniform germination of the plants. Subsequently, irrigation was repeated every 5 to 7 days, depending on the climatic conditions of the region. When 50% of the field reached the flowering stage, harvest operations were carried out in such a way that each half-square meter was marked and labeled. Then, harvesting from the designated area began. The harvest of savory involves only flower picking, which was done by hand. After harvesting, the flowers were immediately dried in the shade. Then, samples from each experimental unit were separately dried in the shade for 5 days. The essential oil extraction process was carried out using a Clevenger apparatus available at the National Institute of Forests and Rangelands. Consequently, a 100-gram sample of dried flowering shoots from each plot was prepared, which was then powdered using an electric mill and placed with 1 liter of water in the Clevenger apparatus flask. It was then heated for 3.5 hours using a heater, during which time distillation occurred with the aid of the cooler of the essential oil extractor, forming the essential oil. Then, the essential oil was extracted, and the weight of the essential oil from 100 grams of dried flowers and the percentage of essential oil from dried flowers were calculated (Kapoor et al., 2004). Statistical analyses were performed using SAS software. Means were compared using the Duncan multiple range test at a 5% significance level,

3. Results

3.1 Plant height

The maximum plant height (46.43 cm) was observed under the interactive effect of the treatment involving 5 tons per hectare of vermicompost and the mycorrhizal fungi G. intradices and G. mosea. Conversely, the shortest plant height (34.83 cm) was recorded in the treatment where no vermicompost and no mycorrhizal fungi were used (Figure 1). This indicates that vermicompost, in conjunction with mycorrhizal fungi, exerts a significant influence on plant growth factors, resulting in an increase in plant height.

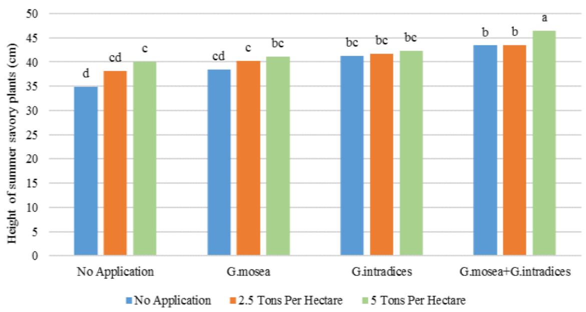

Fig. 1. Interactive effect of various levels of vermicompost and mycorrhizal fungi on the height of summer savory plants

3.2 Flowering shoot yield

The comparison of average levels of vermicompost application on the flowering shoot yield of summer savory plant demonstrates that the highest yield of flowering shoots (1853.77 kg ha^{-1}) was obtained in the treatment with 5 tons of vermicompost per hectare, while the lowest yield (1610.58 kg ha^{-1}) was observed in the treatment without vermicompost application (Table 4). Additionally, the results of comparing the average levels of mycorrhizal fungi indicate that the highest yield of flowering shoots (2073.99 kg ha^{-1}) is associated with the treatment combining *G. intradices* and *G. mosea* fungi, whereas the lowest yield (1408.23 kg ha^{-1}) is related to the non-use of mycorrhizal fungi (Table 5).

3.3 Biological yield

Comparison of various levels of vermicompost indicates the highest biological yield of summer savory plants (6953.07 kg ha^{-1}) in the treatment of 5 tons of vermicompost per hectare, while the lowest biological yield (6365.85 kg ha^{-1}) was obtained in the non-use of vermicompost treatment (Table 4). Results of comparing the mean effects of mycorrhizal fungi levels on the biological yield of summer savory demonstrate that the highest biological yield (7323.74 kg ha^{-1}) was achieved in the treatment inoculated with *G. intradices* and *G. mosea* fungi, whereas the lowest biological yield (6052.45 kg ha^{-1}) was observed in the treatment without the use of mycorrhizal fungi (Table 5).

3.4 Essential oil percentage

The results obtained from the analysis of variance table indicate that the effect of different levels of vermicompost and levels of mycorrhizal fungi on the percentage of essential oil in savory plants is significant (Table 3). However, the application of mycorrhizal fungi levels has had a significant effect on the percentage of essential oil. The results indicate that the percentage of essential oil has increased with the increase in vermicompost consumption. The highest percentage of essential oil (1.25%) was obtained with the consumption of 5 tons per hectare of vermicompost, while the lowest percentage of essential oil (0.99%) was obtained with no vermicompost consumption (Table 4). The results of comparing the mean effect of mycorrhizal fungi levels on the percentage of essential oil in savory plants show that the highest percentage of essential oil (1.28%) was achieved with the use of *G. mosea* and *G. intraradices* fungi, while the lowest percentage of plant essential oil (0.91%) was obtained in the treatment without mycorrhizal fungi (Table 5). This indicates that mycorrhizal fungi contribute to an increase in the percentage of essential oil.

3.5 Essential oil yield

The results obtained from the analysis of variance table indicate that the effect of different levels of vermicompost and levels of mycorrhizal fungi on the yield of savory essential oil is significant (Table 3). Comparing the mean levels of vermicompost on the yield of savory essential oil shows that the highest yield of essential oil (23.71 kg ha^{-1}) was achieved with the consumption of 5 tons per hectare of vermicompost, while the lowest yield of essential oil (17.30 kg ha^{-1}) was obtained in the treatment without vermicompost consumption (Table 4). The results of comparing the mean effect of mycorrhizal fungi levels on the yield of savory essential oil show that the highest yield of essential oil (23.70 kg ha^{-1}) was achieved in the treatment with *G. intraradices* and *G. mosseae* fungi, while the lowest yield of essential oil (15.02 kg ha^{-1}) was obtained in the treatment without mycorrhizal fungi consumption (Table 5).

4. Discussion

4.1 Plant height

The results of Valinezhad et al. (2019) indicated that an increase in plant height was achieved in the treatment with vermicompost along with inoculation of the fungus *Glomus mosseae*. They noted that the application of *Glomus mosseae* alongside vermicompost had a positive effect on this trait. Generally, crucial reasons for the influence of vermicompost and mycorrhizal fungi on increasing plant height include their role in enhancing intrnodes elongation. Regarding the effect of beneficial microorganisms on increasing plant height, it should be noted that this is likely due to the increase in nutrient absorption facilitated by mycorrhizae and their impact on improving photosynthesis and consequently plant growth. Gutierrez et al. (2007), through their investigation on the effect of vermicompost on quantitative and qualitative characteristics of tomato plants (*Lycopersicon esculentum* Mill.), reported that the plant height 85 days after transplantation was significantly greater than that of the control group. Similarly, Darzi et al. (2011) reported that vermicompost, due to its water retention capacity and providing favorable conditions for both highly and lowly consumed nutrients, leads to an increase in the height of medicinal plant anise through its positive impact on photosynthesis, which is consistent with the findings of this study.

The results of the experiment conducted by Tadayon and Zarei (2014) indicated that the height of the plants during flowering stage was greater in plants inoculated with the mycorrhizal fungus *Glomus mosseae* compared to those without inoculation. Plants with mycorrhiza improve their nutritional status, leading to an increase in the transfer of nutrients to the plant and consequently promoting plant growth (Hammer et al., 2011). Additionally, in the investigation of the effect of foliar application of compost extract on the nutrition and growth indices of Dieffenbachia and Aglaonema, it was demonstrated that foliar application of compost extract significantly affected growth indices such as plant height (Mahboub Khomami, 2005).

Joshi et al. (2013) demonstrated that the application of vermicompost led to an increase in the average height of wheat plants and stem diameter compared to the control group. Similarly, Shirzadi *et al*. (2014) reported that the simultaneous use of vermicompost, mycorrhizae, and azotobacter resulted in an increase in the height of basil plants. Additionally, Tahami Zarandi (2010) observed that the use of organic and biological fertilizers increased the height of basil plants.

4.2 Flowering shoot yield

The results of the study conducted by Haj Seyed Hadi and Darzi (2018) on the medicinal plant summer savory indicated a significant effect of vermicompost on the yield of flowering shoots. An increase in the amount of vermicompost led to an increase in the yield of flowering shoots compared to the control treatment. The highest dry matter yield of flowering shoots was obtained with the application of 15 tons of vermicompost per hectare. According to the report by Atiyeh et al. (2000), adding vermicompost derived from animal manure up to 90% of the volume of pots increases the vegetative growth and flowering of marigolds. The results of the study by Anwar et al. (2005) showed that the application of vermicompost increases flower yield in basil plants. The increase in vermicompost amounts, through its effects on absorption capacity, moisture retention, and the provision of nutrients such as nitrogen, phosphorus, and potassium, enhances the yield components of fennel, such as the number of flowers per plant and the hundred-flower weight, leading to improved flower yield (Darzi et al., 2008). In their study on blacksamson echinacea (*Echinacea angustifolia*), Razavi Nia et al. (2015) reported that the application of vermicompost led to an increase in the fresh and dry weight of flowers. They also mentioned that vermicompost, being mixed with soil from the beginning of land preparation, improved the physical conditions and vital processes of the soil, preserved moisture at the soil surface, and gradually released nutrients during the long growth period of the plants. By creating a suitable root growth environment, vermicompost contributed to increased dry matter production and flower yield. The increase in the amount of vermicompost resulted in an increase in the dry weight of flowers, with the lowest weight (8.39 grams per square meter) and the highest weight (14.33 grams per square meter) belonging to the treatments of applying 5 and 20 tons of vermicompost per hectare, respectively (Ghazi Manas et al., 2013).

The results of Darzi et al. (2008) demonstrated a significant difference between levels of mycorrhizal inoculation, with a notable increase in the number of umbels per plant in mycorrhizal-inoculated plants (41.5 umbels) compared to non-inoculated ones (34.9 umbels), representing an approximately 18.9% increase. They also stated that mycorrhizal symbiosis, through proper nutrition and increased plant biomass of fennel, facilitated accelerated flowering and improved umbel numbers per plant. Furthermore, the improvement in water uptake and plant nutrition resulting from mycorrhizal symbiosis led to increased flowering. The findings of Fadaee et al. (2018) indicated that the highest number of flowers per plant occurred at 65% of the farm capacity with the use of *G. mosseae* mycorrhizal fungi and phosphate fertilizer.

4.3 Biological yield

The addition of vermicompost to soil may not only increase the availability of essential nutrients for savory plants but also improve the physical conditions and vital biological processes of the soil, thereby creating a suitable environment for root growth. This, in turn, promotes the growth of aerial organs such as height and the number of umbels per plant and subsequently enhances dry matter production (Darzi et al., 2008). Regarding the effect of mycorrhizal symbiosis on the biological yield of fennel, it can be inferred that the enhancement of photosynthesis rate and growth leads to an increase in plant biomass and ultimately biological yield. In this regard, Kapoor et al. (2004) also obtained similar results.

The findings of the study conducted by Salehi et al. (2016) indicate that increasing the application of vermicompost significantly enhances the biological yield of chamomile, with the highest biological yield achieved with the application of 10 tons of vermicompost per hectare. Similarly, similar results have been reported by Akbarinia et al. (2003) in this regard. The addition of vermicompost to soil not only improves the biological conditions of the soil but also provides the nutritional prerequisites for enhancing the growth of aerial organs such as height, flower count per plant, vegetative mass, and biomass production (Anwar et al., 2005). Studies conducted by Darzi et al. (2006) on fennel plants demonstrated that vermicompost led to an increase in the biological yield. In another study, Abdullah et al. (2012) investigated the effect of different levels of vermicompost on some morphological traits of rosemary plants. The results indicated that the highest number of lateral branches, fresh weight, and dry weight of the plant were obtained in the treatment with 8 tons per hectare of vermicompost.

Darzi and colleagues (2008) reported a significant difference in mycorrhizal inoculation levels, where the biological yield in mycorrhizal inoculation (5350 kilograms per hectare) was approximately 19.4% higher compared to non-inoculated conditions (4480 kilograms per hectare). Regarding the effect of mycorrhizal symbiosis on the biological yield of fennel plants, it can be inferred that the improvement in photosynthesis rate and growth leads to an increase in plant biomass and ultimately biological yield. The findings of Gupta et al. (2002) elucidated that the mycorrhizal symbiosis with the roots of mint plants enhances water and nutrient absorption, consequently increasing photosynthesis, leading to higher production rate and improved biological yield. Similarly, research by Kapoor et al. (2002) on dill and caraway also supports the notion that mycorrhizal symbiosis enhances the biological yield of these medicinal plants. Research by Joshee et al., (2007) regarding the medicinal plant, skullcaps, demonstrated that root inoculation of this plant with mycorrhizae resulted in increased plant growth. Additionally, in the study by Nagananda et al. (2010), it was observed that the application of biological fertilizers (mycorrhizal fungi and azotobacter) on fenugreek plants led to an increase in the biological yield of the plant.

4.4 Essential oil percentage

In interpreting the results obtained from the improvement in the level of essential oil due to the application of fungal biofertilizers, it can be stated that since essential oils are terpenoid compounds, their constituent units (isoprenoids) such as isopentenyl pyrophosphate (IPP) and dimethylallyl pyrophosphate (DMAPP) require ATP and NADPH. Considering that the presence of elements such as nitrogen and phosphorus is essential for the formation of these compounds, fungal and bacterial biofertilizers through the positive impact on the activity of phosphate-solubilizing microorganisms, potassium, nitrogen-fixing microorganisms, and other beneficial microorganisms in the soil, can provide favorable access to both high and low-consumption nutrients by the fennel plant. Consequently, this could contribute to the improvement of the percentage of essential oil. In an experiment conducted on ajwain plants, it was observed that the use of phosphate-solubilizing bacteria led to a significant increase in the percentage of essential oil. This increase can be attributed to the provision of photosynthetic materials (Eblagh et al., 2013). In another experiment, the effect of inoculation with mycorrhizal fungi on the level of fennel and ajwain essential oils was significant. Under mycorrhizal inoculation conditions, the percentage of fennel and ajwain essential oils was 4.2% and 3%, respectively. The researchers attributed the increase in the percentage of essential oil to the improvement of soil microbial activity and the production of certain plant growth regulators that enhance plant photosynthesis (Koocheki et al., 2015). Darzi and colleagues (2009) stated that mycorrhizal symbiosis, through efficient absorption of phosphorus and to some extent nitrogen by fennel roots, leads to an increase in the essential oil of this medicinal plant.

Research on dill and caraway species indicates that the application of two species of mycorrhizal fungi, namely *Glomus macrocarpum* and *Glomus fasciculatum*, significantly improves the percentage of essential oil in these plants compared to the control. Dill showed up to

90% superiority in the percentage of essential oil, while caraway showed up to 72% superiority compared to the control treatment. In this study, the increased uptake of mineral phosphorus by mycorrhizal plants, which is an essential element in the biosynthesis of essential oils, was identified as a significant factor in increasing the percentage of essential oil (Kapoor et al., 2002).

In a study conducted by Anwar et al. (2005) on basil medicinal plant, the results showed that the application of vermicompost along with chemical fertilizer had a positive effect on the percentage of essential oils in plants compared to control plants. The researchers of this study stated that adding vermicompost, through improving nutrient absorption and enhancing physical conditions, along with improving root and aerial organ growth, resulted in improved mineral nutrient uptake, leading to an increase in essential oil content. Similarly, Mafakheri et al. (2012) reported significant effects of different levels of vermicompost on the percentage of essential oils in *Dracocephalum moldavica* medicinal plants.

4.5 Essential oil yield

In the production of medicinal plants, the real value is attributed to the quality of the product, namely the level of active ingredients, and it has been observed in research conducted using biofertilizers in this field that the maximum active ingredient is obtained under such conditions. In the study by Azizi et al. (2006), the results showed that desirable treatments with biofertilizers, compared to the control (non-inoculated), significantly improved the conditions for enhancing beneficial microbial activities in the soil and providing essential mineral elements for caraway. Through creating synergistic and enhancing effects, they are capable of increasing the yield of essential oil and its components in the plant.

Zamani et al. (2018) reported that a combined treatment providing favorable conditions for nutrient uptake, particularly nitrogen, phosphorus, and micronutrients (iron, manganese, zinc, and copper), resulted in an increase in the essential oil of fennel medicinal plant. Their results indicate that secondary metabolites are byproducts of photosynthesis, and considering that the highest yield was obtained in the combined treatment and the vegetation of plants with biological fertilization sources improved due to the suitable and proportional provision of nutrients (N, P, K) compared to other treatments, the production of secondary metabolites in these plants increased, allocating the highest volume of essential oil production to themselves. It appears that increasing the availability of nutrients for the plant and promoting growth as a result of inoculation with mycorrhizal fungi and phosphate-solubilizing biofertilizer bacteria have had a significant effect on the yield and yield components of caraway. This has notably impacted the percentage and yield of essential oil (Zamani et al., 2018).

In a study on coriander, the essential oil yield increased due to the application of mycorrhizal fungi. The seed yield and the amount of essential oil in the seeds are considered as components of coriander essential oil yield. Therefore, the increase observed in these two components due to mycorrhizal inoculation resulted in an increase in the essential oil yield (Kapoor et al., 2002). The results of Eslami Fard et al. (2019) demonstrated that the application of mycorrhizal fungi under water-limited conditions also had a significant effect on the percentage and yield of peppermint essential oil. The application of *G. mosseae*, *G. hoi*, and *G. intraradices*, as well as a combination of all three species, increased the production of essential oil. Hazzoumi et al. (2015) demonstrated that the application of mycorrhizal fertilizer along with water scarcity resulted in the highest yield of Ocimum gratissimum essential oil. Arango et al. (2012) showed that plants treated with mycorrhizae had greater fresh weight, dry weight, and leaf area compared to non-mycorrhizal plants. Mycorrhizal treatment led to an increase in phosphorus, potassium, and calcium content in aerial parts. This treatment also increased the percentage and yield of essential oil in peppermint.

The results presented by Asghari et al. (2016) indicated that the main effect of compost and vermicompost, as well as their interaction, on the percentage of essential oil, were statistically significant at the one percent probability level. The percentage of essential oil was significantly increased under the influence of compost and vermicompost, with the third level of municipal waste compost and vermicompost resulting in a 20 and 26.92 percent increase in essential oil, respectively. The consumption of compost along with vermicompost also led to an increase in the percentage of essential oil, with the highest percentage of essential oil (1.13 percent) obtained in the treatment of 20 percent compost combined with 20 percent vermicompost. Khalil et al. (2006) stated that compost resulted in increased vegetative growth, essential oil, and some components of essential oil in basil plants.

5. Conclusion

The results of this study indicate that different levels of vermicompost and mycorrhizal fungi had a significant impact on the savory plant. Specifically, the application of 5 tons per hectare of vermicompost resulted in the highest percentage of essential oil (1.25%), the highest essential oil yield (23.71 kilograms per hectare), the highest percentage of γ-Terpinene (44.50%), and the highest percentage of α-Terpinene (4.21%). Furthermore, at different levels of mycorrhizal fungi, the highest percentage of essential oil (1.28%), essential oil yield

(23.70 kilograms per hectare), the highest percentage of γ-Terpinene (45.35%), and the highest percentage of α-Terpinene (4.45%) were obtained with the combination of *G. intradices* and *G. mosea* fungi. The interactive effect of different levels of vermicompost and mycorrhizal fungi resulted in the highest percentage of ρ-Cymene (3.14%) in the treatment with 5 tons per hectare of vermicompost combined with *G. intradices* and *G. mosea* fungi, and the highest percentage of carvacrol (40.70%) in the treatment with 2.5 tons per hectare of vermicompost combined with *G. intradices* and *G. mosea* fungi. The use of vermicompost led to a significant increase in the yield of essential oil and its components. Moreover, the application of *G. intradices* and *G. mosea* fungi resulted in an increase in the percentage and yield of the essential oil, as well as its components, compared to the control treatment.

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