Effect of Organic Fertilizers on Nutrients Content and Essential Oil Composition of Savory (*Satureja hortensis* L.)

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Submission: September 16, 2017; Acceptance: October 29, 2018

ABSTRACT

Application of organic fertilizers in the production of plants is aimed to eliminate or substantially reduce the use of chemical inputs and improve the growth and quality of plants. For instance, in present study, the effect of vermicompost and spent mushroom compost application on nutritional status and essential oil components of summer Savory (*Saturejahortensis* L.) was investigated. This experiment was conducted in the research greenhouse of Faculty of Agriculture at Mohaghegh Ardabili University using a layout of completely randomized design with five replications on Savory in 2014. Experimental treatments included different substrates that contained vermicompost, washed and unwashed spent mushroom compost in five levels (10, 20, 30, 40 and 50 Percent v/v). After flowering, the plants were harvested and parameters such as leaf area, leaf and plant dry weight, chlorophyll index of leaf and N, P, K, and Ca content and essential oil component of plants were measured. The results showed that the effect of organic substrates on macronutrient content and savory's growth parameters was significant. The highest Nitrogen content (6.3%) and Phosphorus (0.98%) in savory shoot was obtained in a substrate supplemented with 40% vermicompost. Plants grown in the media containing 30% of vermicompost and 50% of washed spent mushroom compost (SMC) have higher potassium (3.19%) and calcium (2.48%) content, respectively. The lowest nitrogen, phosphorus and potassium content in the aerial part was obtained in the control treatment. Moreover, application of organic fertilizers significantly affected on savory's essential oil percentage and compounds composition. The highest and lowest essential oil contents were obtained in plants in substrates containing 30 % of vermicompost and unwashed spent mushroom compost respectively. The main components of essential oil were carvacrol and gamma-trepenine. The highest level of carvacrol (62.10) and gamma-trepenine (32.05) were obtained in plants in substrates containing 40 and 20% of washed spent mushroom respectively.

Keywords: Essential oil; leaf area index, nutrients, savory, vermicompost

INTRODUCTION

Summer savory (*Satureja hortensis* L.) is an annual and herbaceous plant belonging to the Lamiaceae family. This herb is native to Mediterranean region (Hadian *et al.,* 2008) with small flowers (1.5 mm) and long leaves. The leaves contain essential oil and compounds (Omidbeigi, 2000) such as phenols, carvacrol, thymol, beta caryophyllene, linalool and terpenoids (Omidbaigi and Hejazi, 2004). Savory is widely used in culinary applications and as an herbal medicine to boost sexual potency and to treat paroxysm and bloating (Hadian *et al.,* 2008; Hidalgo *et al.,* 2002).Today, economic and environmental impacts due to extensive use of chemical fertilizers are becoming globally threatening so an appropriate alternative for this type of fertilizers should be substituted (Gholami Sharafkhane *et al.,* 2015).

A global approach in medicinal plants production is to establish a sustainable system and to apply management practices. Composts are among the most common organic fertilizers used in sustainable agricultural systems (Kiani *et al.,* 2014; Nooshkam *et*

DOI: http://doi.org/10.22146/agritech.28324
ISSN 0216-0455 (Print), ISSN 2527-3825 (Online)

al., 2015; Sharma, 2002). About 38 billion cubic meters of organic material are produced annually by humans, animals and plants around the world. This volume of waste can be recycled to a variety of agricultural fertilizers, including compost and vermicomost, (Asghari *et al.,* 2012; Sharma, 2002).

Vermicompost is one of the organic fertilizers, produced as a result of earthworms' activity on organic materials. Vermicompost has high porosity, nutrients retention capacity, ventilation and drainage, microbial activity and water storage capacity (Sangwan *et al.,* 2008). In addition, vermicompost is rich in vitamins, enzymes beneficial microorganisms and plant growth regulators such as auxins, gibberellins and cytokinins (Hidalgo *et al.,* 2002; Frankenberger *et al.,* 1995; Locanzo *et al.,* 2009; Singh *et al.,* 2003; Atiyeh *et al.,* 2000; Arancon *et al.,* 2007). Furthermore, vermicompost increases nitrogen and phosphorus availability for plants (Pradha *et al.,* 2007; Tiwari *et al.,* 1989).

Spent mushroom compost (SMC) is another type of organic fertilizers which can be used as soil amendment. SMC is rich in micro and macro nutrients and is used as for improving soil structure, ventilation and microbial activity (Betnal *et al.,* 1998; Arthur *et al.,* 2012; Courtney *et al.,* 2008; Gonani *et al.,* 2011; Ratti *et al.,* 2001). Although the importance of SMC is well established in the world, the literature on its application in Iran is scanty so that SMC is still considered as waste material (Philippoussis *et al.,* 2004). (Peregrina *et al.,* 2009) showed that SMC application not only increases soil organic matter and nitrogen content, buts also improves soil structure (Peregrina *et al.,* 2009).

In a study, application of cattle manure, vermicompost and biologic fertilizers including nitroxin, bio-sulfur, bio-phosphorus and combination of them could increase growth indexes and essences content compared with control treatment (Gholami Sharafkhane *et al.,* 2015). In addition, increase in plant height, branches number, flower dry weight, shoot dry weight and essence percentage have been reported in savory treated with chemical and bio-fertilizers (Makkizadeh Tafti *et al.,* 2012) Moreover, (Hossaini *et al.,* 2015) have reported that the maximum essence percentage in savory plants (*Satureja sahandica*) was obtained when 2 ton ha^{-1} vermicompost was applied (Hossaini *et al.,* 2015). Positive effects of biological and organic fertilizers on savory and essential oil content have been documented by several authors (Naeeji *et al.,* 2015; Rezvani-Moghadam *et al.,* 2013).

In a similar study on dragonhead (*Dracocephalum moldavica*), (Mafakheri *et al.,* 2012) have shown that vermicompost, azotobacter and bio-phosphate application increased morphophysiological attributes and essence content (Mafakheri *et al.,* 2012). Vermicompost application could also increase vegetative growth and essence content in basil (Anwar *et al.,* 2005). Given the importance and role of medicinal plants in human life, it is important to increase their production without the use of chemical inputs (Mafakheri *et al.,* 2012). Hence, the current study was aimed to evaluate the effects of different vermicompost and SMC amounts on growth, nutrients content and essential oil composition of summer savory and to offer an alternative method to produce chemical free or organic products in a low input system.

MATERIAL AND METHODS

The current study was carried out as a pot experiment under greenhouse conditions based on a completely randomized design with five replicates at Mohaghegh Ardabili University in 2014. The day/night temperature was set on 25/20±2 and relative humidity was 50-60%. The experimental treatments consisted of 16 treatments: 10, 20, 3, 40 and 50% v/v vermicompost, 10, 20, 3, 40 and 50% v/v washed SMC and 10, 20, 3, 40 and 50% v/v unwashed SMC and one control. There were two pots for each replicate and four plants in each pot. Soil, vermicompost and SMC physicochemical are given in (Table 1).

SMC was washed to reduce salinity. Growth media consisted of three parts soil and one part sand. Different ratio of vermicompost and SMC were determined and mixed into growth media. Savory seeds (3 ☐ 4 seeds) were sown in small plastic pots in May. After 4 weeks seedlings were transplanted into the main pots (30 × 35 × 25). Irrigation was performed every two days (1 liter)

Table 1. Physicochemical properties of organic fertilizers and soil before starting of experiment

Soil	Vermicompost	Unwashed SMC	Washed SMC	Properties
0.068	35	79	42	(%)OC
0.014	3.51	0.378	0.25	(%)N
0.08	1.15	1.58	1.1	(%)P
0.03	1.25	1.53	1.18	(%)K
11.48	550	598	510	($mg.kg^{-1}$)Fe
10	300	320	290	($mg.kg^{-1}$)Mn
3.5	250	380	285	($mg.kg^{-1}$)Zn
0.82	45	52	42	($mg.kg^{-1}$)Cu
7.1	7	7.68	7.1	pH
1.2	1.1	12.88	5.6	($dS.m^{-1}$)Ec

to well establishment of the seedlings. The seedlings were transplanted into the main pots at 3 – 4 true leaf stage. Then irrigation was performed every four days. Chlorophyll index was recorded from 9 leaves across the plants using SPAD-502 (Konica Minolta, Japan). Leaf and plant dry weights were determined for each pot separately. Leaf area was measured on four plants using Leaf Area Meter (ΔT, UK). Leave samples were taken and dried in an oven at 70 °C for 48 to determine nutrients content. Dried samples were grounded and digested using sulfuric acid, salicylic acid, oxygen peroxide and selenium method. Above ground nitrogen content was determined using Kjeldahl method (Emami *et al.,* 2004). Phosphorus content was determined using spectrophotometer method. Potassium and calcium content were determined using flame photometer and titration methods, respectively (Emami *et al.,* 2004).

In order to extract the essential oil four months after sowing leaf samples were collected from upper parts of the plants and dried at room temperature and sunlight protected area until 10-14% moisture content. Essence was extracted using water distillation method using Clevenger apparatus. Extracted oil was dried with sodium sulfate and then weighted. The samples were kept in dark and cool place until further analysis. Gas chromatography (Varian CP 3800) equipped with DB 1 column (25 m, 0.25 mm and 0.25 μm) was used to analyses the essence composition. The data were analyzed using SAS 9.1. The Duncan's multiple range test was used to compare the means.

RESULTS AND DISCUSSION

Chlorophyll, Leaf Dry weight, Plant Dry Weight and Leaf Area

Analysis of variance indicated that the effect of vermicompost and SMC (washed and unwashed) were significant on chlorophyll, leaf dry weight, plant dry weight and leaf area (Table 2). The results indicated that chlorophyll content increased in plants treated with organic fertilizers compared with control treatment. However, there was no significant difference between 10% unwashed SMC ad control treatment. The maximum chlorophyll (54.78 units) was related to 10% vermicompost treatment. By contrast the minimum chlorophyll (27.34 units) was found in control treatment (Table 3). Comparison of means showed that application of vermicompost and SMC (except for 30% vermicompost and 50% SMC treatments) could increase leaf dry weight compared with control treatment.The maximum leaf dry weight (9.7 g per plant) was observed when 10% vermicompost was applied.

On the other hand, the minimum leaf dry weights were found when 30% vermicompost (2.24 g per plant) or 50% washed SMC (2.4 g per plant) were used (Table 3). According to (Table 3), vermicompost and SMC application (except for 30%vermicomoist and 50% washed SMC) could increase plant dry weight compared with control treatment. In addition, the results showed that the maximum plant dry weight (13.31 g per plant) was related to 10% vermicompost treatment. By contrast, the minimum values were obtained from 30% vermicomost (4.50 g per plant) and 50% washed SMC (5.09 g per plant) treatments (Table 3). Moreover, comparison of means indicated that 20 and 40% vermicompost treatments produced the maximum leaf area (38.0 and 38.36 cm^2, respectively) whereas the control treatment showed the minimum leaf area (25.62 cm^2) (Table 3). Vermicompost is rich in micro and macro nutrients as well as humic acid (Joshi *et al.,* 2015). It seems that organic fertilizers improve plant growth and biomass production through increasing nutrients availability (Yousefi *et al.,* 2015).

On the other hand, organic fertilizers help plants to better grow by improving soil physical properties, biological activity and water retention capacity (Naiji *et al.,* 2015). In addition, vermicompost contains hormonal compounds which help plants produce more biomass and build strong roots and fight diseases (Bachman and Metzger, 2007). Increase in leaf area has been reported by (Mcginnis *et al.,* 2003) who applied vermicompost on basil plants and stated that vermicompost improves soil physical properties, microorganisms' activity and soil water retention capacity (Mcginnis *et al.,* 2003). Considering this fact that zinc plays a key role in synthesis of indole acetic acid and vermicompost is rich in this element (Table 1), increase in plant growth and dry matter production on account of vermicompost application is not surprising (Adinarayana and Kumar, 2006).

Increase in dry matter due to vermicompost application has been previously reported by (Muscolo *et al.,* 1999). In addition, (Naiji and Souri, 2015) have reported that the maximum plant height, leaf area, leaf number, stem diameter and fresh and dry weight in savory were obtained when 20% vermicompost was applied (Naiji and Souri, 2015). In a study, in order to study the effects of organic and chemical fertilizers on growth and yield of savory, the maximum biological yield was obtained when vermicompost was used whereas the maximum plant height, branch number and biomass was obtained when phosphate soluble treatment was applied (Rezvani Moghaddam *et al.,* 2013). Increase in plant height and branch number in savory on account of 7 ton ha^{-1} vermicompost has been reported by (Gholami-

Sharafkhane *et al.,* 2015). Similarly, increase in growth paramters in *(Satureja sahandica*) (Hossaini *et al.,* 2015), basil (Rezaee Moadab and Nabavi Klat, 2012; Rezaeifar, and Alizadeh Oskuie, 2015), dragonhead (Darzi and Haj Seyed Hadi 2015; Mafakheri *et al.,* 2012) and *Dracocephalum* (Abbaszadeh and Zakerian, 2016; Neamati *et al.,* 2014), have been reported. Our results are in agreement with these findings. According to other results in this research, correlation between chlorophyll index (SPAD) and dry matter weight was positive and significant (Table 6). Also, the correlation between leaf area and dry weight was positive and significant (Table 6). In addition, the correlation of nitrogen with leaf erea was positive and significant (Table 6). It seems that nitrogen supply, through increased leaf area, increases plant dry weight and the increase of chlorophyll content, can be effective in increasing the plant dry matter by increasing the photosynthetic capacity of the plant.

Nitrogen, Phosphorus, Potassium and Calcium Concentration

The analysis of variance indicated that the effect of organic fertilizers was significant on nitrogen, phosphorus, potassium and calcium concentration in above ground parts of savory plants (Table 2). In addition, comparison of means revealed that organic fertilizers could increase nutrients content in above ground parts of savory compared with control treatment

Table 2. Analysis of variance of the effects of different level of vermicompost and spent mushroom compost on vegetative growth characteristic and macro elements content of summer savory foliage

Source of Variation	Means of squares								df
	Calcium	Potassium	phosphorus	Nitrogen	Leaf area	Leaf dry weight	Plant dry weight	Greening index of leaf	
Treatment	26.22**	414.82**	316.20**	0.06**	**0.68	**359.67	**484.4	**150	15
Error	1.03	7.89	7.61	20.00	1.09	5.03	3.55	3.3	64
(%) CV	12.39	6.34	4.29	6.65	3.3	9.13	5.23	5.02	

** significant at 1% probability level

Table 3. Mean Comparison for effects of spent mushroom compost and vermicompost on vegetative growth Characteristic and macro elements content in aerial parts of summer savory

Treatment		Calcium (%)	Potassium (%)	Phosphorus (%)	Nitrogen (%)	dry weight (g/stand)	Leaf area (cm^2/pot)	Plant dry weight (g/stand)	Greening index of leaf (spad)
(control)		1.02^{cd}	0.87^{g}	0.47^{g}	2.15^{f}*	4.23^{i}	25.62^{h}	6.65^{i}	29.86^{f}
10	Unwashed spent mushroom compost (%)	0.9^{d}	2.1^{f}	0.81^{cd}	2.5^{ef}	5.86^{fg}	28.42^{g}	8.25^{fg}	30.76^{ef}
20		1.2^{bcd}	2.05^{f}	0.89^{bc}	2.55^{ef}	5.86^{hi}	28.9^{fg}	7.42^{h}	33^{de}
30		1.38^{bc}	3.06^{ab}	0.86^{bc}	3.75^{cd}	4.67^{hi}	30.78^{de}	7.95^{gh}	32.72^{de}
40		2.42^{a}	3.00^{b}	0.82^{bcd}	3^{de}	7.0^{d}	31.98^{cd}	9.55^{d}	33.24^{d}
50		2.4^{a}	2.53^{cd}	0.76^{de}	2.65^{ef}	6^{f}	30.02^{ef}	8.81^{ef}	36.54^{c}
10	washed spent mushroom compost(%)	1.01^{cd}	2.7^{c}	0.72^{e}	3.85^{c}	7.8^{c}	31.34^{cde}	10.85^{c}	36.36^{c}
20		1.03^{cd}	2.3^{e}	0.84^{bcd}	3.45^{cd}	5.17^{gh}	31.6^{cd}	7.64^{h}	41.76^{b}
30		1.37^{bc}	2.34^{e}	0.54^{fg}	3.45^{cd}	7.93^{c}	30.96^{de}	11.33^{bc}	42.55^{b}
40		1.32^{bc}	2.38^{de}	0.88^{bc}	5.25^{b}	8.35^{bc}	35.14^{b}	11.34^{bc}	33.16^{d}
50		2.48^{a}	2.66^{c}	0.82^{bcd}	6.1^{ab}	9.6^{j}	30.2^{ef}	5.09^{j}	32.54^{de}
10	Vermicompost (%)	1.51^{b}	2.61^{c}	0.59^{f}	3.3^{cde}	9.7^{a}	34.06^{b}	13.31^{a}	54.78^{a}
20		1.55^{b}	2.08^{f}	0.9^{ab}	5.9^{ab}	6.81^{de}	38.36^{a}	9.96^{d}	34.14^{d}
30		2.11^{a}	3.19^{a}	0.91^{ab}	6^{ab}	6.7^{j}	27.92^{g}	4.55^{j}	38.1^{b}
40		2.38^{a}	2.60^{c}	0.98^{a}	6.2^{a}	8.7^{b}	38.04^{a}	11.86^{b}	41.96^{b}

*Similar letters in each column have not significant difference based on Duncan test at 5% probability level.

Table 4. Analysis of variance of the effects of different level of vermicompost and spent mushroom compost essential oil percentage and essential oil components of summer savory

S.O.V		Means of squares									
		P-Cymene	Alpha-Terpinene	Delta-3-Carene	Alpha Phellandrene	Alpha-Thujene	Myrcene	Terpinol	Gamma-Terpinene	Carvacrol	essential oils
Treatment	15	1.55*	0.033^{**}	0.66*	0.04**	0.024**	0.53*	30.73^{**}	26.43 *	0.55^{**}	0.085^{**}
Error	64	0.287	0.11	0.005	0.005	0.011	0.67	18.16	14.94	0.318	0.001
CV		20.10	15.68	26.2	22.5	14.75	21.77	6.66	14.83	28.46	1.57

** is significant difference at 1% probability level

(Table 3). The maximum nitrogen (6.2%) and phosphorus (0.98%) content was observed in 40% vermicompost treatment. There was no significant difference between 20, 30 and 40% vermicompost treatments. The maximum potassium content (3.19%) was also obtained from 30% vermicompost treatment. There was no significant difference between 30% vermicompost and 30% unwashed SMC (3.06%) treatments in terms of potassium content. The maximum calcium content was related to 30, 40 and 50% vermicompost treatments and 50% washed SMC as well as 40 and 50% unwashed SMC treatments. The minimum nitrogen, phosphorus and potassium (2.15, 0.47 and 0.87%) were observed in control treatment, whereas the minimum calcium content (0.9%) was related to 10% unwashed SMC treatment (Table 3).

According to the results vermicompost application could increase nitrogen content in plant tissues compared with control treatment and other treatments. This might be due to these facts that vermicompost not only provides more nitrogen in the form of nitrate (Joshi *et al.,* 2015) it increases soil cation exchange capacity and soil buffering properties (Theunissen et al., 2010). Increase in nitrogen uptake due to 20% vermicompost application in summer savory (Naiji and Souri, 2015) and dragonhead (Abbaszadeh and Zakerian, 2016) has been previously reported. (Darzi and Haj Seyed Hadi, 2016) reported that the maximum nitrogen content was related to 10 ton ha^{-1} vermicompost + biological fertilizers compared with cattle manure, biological fertilizer and combination of them (Darzi and Haj Seyed Hadi, 2016). (Ahmad Abadi *et al.,* 2011) have also found that application of vermicompost for three consecutive years could increase iron and zinc content in borage leaves and flowers (Ahmad Abadi *et al.,* 2011). Our results are in agreement with these findings. The results indicate that

Table 5. Mean comparison the effects of different level of spent mushroom compost and vermicompost on essential oils component of summer savory

Treatment		P-Cymene (%)	Alpha-Terpinene (%)	Delta-3-Carene (%)	Alpha-Phellandrene (%)	Alpha-Thujene (%)	Myrcene (%)	Terpinol (%)	Gamma-Terpinene (%)	Carvacrol (%)	Essential oils (%)
(control)		2.23^{a}	1.46^{b}	0.35^{d}	0.13^{f}	0.63^{ab}	0.55^{d}	2.40^{b}	31.15^{ab}	60.90^{ab}	0.34^{c}
10	Unwashed spent mushroom compost (%)	2.3^{a}	1.34^{bc}	0.2^{de}	0.25^{ef}	0.71^{a}	1.30^{ab}	2.45^{c}	31.40^{ab}	60.05^{b}	0.5^{b}
20		2.2^{a}	1.40^{b}	0.41^{cd}	0.49^{b-e}	0.74^{a}	1^{bcd}	2.65^{ab}	30.81^{b}	60.3^{ab}	0.35^{c}
30		2.16^{ab}	1.27^{bc}	0.23^{de}	0.61^{b}	0.6^{b}	1.05^{bc}	2.80^{a}	30.26^{bc}	61.1^{ab}	0.25^{c}
40		1.55^{bc}	1.06^{c}	0.71^{ab}	0.77^{a}	0.56^{bc}	1.35^{b}	2.60^{b}	30.8^{b}	60.80^{ab}	0.32^{c}
50		1.39^{c}	1.6^{ab}	0.90^{a}	0.3^{ef}	0.64^{ab}	1.50^{a}	2.20^{c}	30.45^{bc}	61^{ab}	0.28^{c}
10	washed spent mushroom compost(%)	2.25^{a}	1.45^{b}	0.6^{b}	0.2^{ef}	0.65^{ab}	1.30^{ab}	2.70^{a}	31.2^{ab}	59.65^{b}	0.55^{b}
20		1.54^{b}	1.2^{bc}	0.14^{f}	0.71^{ab}	0.51^{c}	1.10^{b}	2.10^{cd}	32.05^{a}	60.65^{ab}	0.39^{c}
30		1.15^{c}	1.76^{a}	0.24^{de}	0.35^{de}	0.7^{a}	1.20^{b}	2.70^{a}	30.70^{b}	61.2^{ab}	0.45^{bc}
40		1.43^{b}	1.42^{b}	0.15^{g}	0.95^{a}	0.6^{b}	0.70^{c}	2.95^{a}	29.70^{c}	62.10^{a}	0.38^{c}
50		1.66^{ab}	1.69^{a}	0.77^{a}	0.41^{d}	0.68^{ab}	1.05^{bc}	2.6^{b}	28.3^{d}	62.90^{a}	0.35^{c}
10	Vermicompost (%)	2.15^{ab}	1.42^{b}	0.44^{c}	0.45^{d}	0.69^{ab}	0.75^{c}	2.65^{ab}	31.3^{ab}	60.15^{b}	0.38^{c}
20		1.8^{b}	1.6^{ab}	0.32^{d}	0.22^{ef}	0.66^{ab}	1.05^{bc}	2.80^{a}	30.80^{b}	60.55^{b}	0.42^{bc}
30		1.47^{bc}	1.24^{bc}	0.66^{b}	0.25^{ef}	0.68^{ab}	1.30^{ab}	2.45^{b}	30.60^{b}	61.35^{ab}	0.7^{a}
40		1.79^{b}	1.4^{b}	0.16^{de}	0.38^{de}	0.82^{a}	1.25^{b}	2.85^{ab}	30.80^{b}	60.75^{ab}	0.65^{a}
50		1.24^{c}	1.19^{c}	0.35^{d}	0.24^{ef}	0.58^{bc}	1.15^{b}	2.65^{ab}	31.05^{ab}	61.5^{ab}	0.54^{b}

washed and unwashed SMC could increase nutrients uptake compared with control treatment. However, the effect of vermicompost was more pronounced in comparison with SMC. The application of SMC increases calcium, magnesium, sulfate and potassium availability, hence provides better conditions for plant growth and development (Mir Soheyl and Gholami, 2008; Ratti *et al.,* 2001). In a study, the effect of vermicompost and SMC was found to be significant on plant height, chlorophyll content, leaf area and macro nutrients content in mint plants (Kiani *et al.,* 2014). Increase in nitrogen and potassium content in pepper leaves (Kubilay Onal and Topcuoglu, 2007) increase in soil phosphorus content (Medina *et al.,* 2012) and increase in leaves phosphorus content in some ornamental trees (Chong, *et al.,* 1991) have been previously reported.

Essence Composition

The results showed that the effect of vermicompost and SMC application was significant on essential oil percentage, carvacrol, terpineol, alpha- thujene, alpha phellandrene, alpha-terpinene, gamma-terpinene, myrcene, delta-3-caren and p-cymene (Table 4). In addition, the comparison of means showed that there is a significant difference between fertilizers treatments in terms of essence content and composition (Table 5). The maximum essential oil percentage was found in 30 and 40% vermicompost treatment, whereas the minimum essence percentage was related to 30% washed SMC treatment. There results showed that carvacrol, gamma-terpinene, terpineol and myrcene were the most abundant compounds of essential oil. The maximum carvacrol content was obtained when 40 (62.10) and 50% (62.90) washed SMC was applied. The minimum carvacrol content (59.65) was observed in 10% washed SMC treatment. The maximum (32.05) and minimum (28.3) gamma-terpinene content were related to 20% washed SMC and 50% washed SMC, respectively. The maximum myrcene (1.50) was found from 50% unwashed SMC treatment. The maximum Terpineol was achieved from 30% unwashed SMC (2.80), 20 (2.80) and 40% (2.85) vermicompost treatments. However, there was no significant difference between these treatments and 10 and 30% washed SMC treatments.

The maximum alpha- thujene content was related to 10 (0.71) and 20% (0.74) washed SMC and 40% (0.72) vermicompost. Among essence compounds, the maximum alpha phellandrene (0.95) was obtained from 40% washed SMC treatment. Although there was no signifncat difference between this treatment and 30% unwashed SMC treatment and 20 and 40% washed SMC treatments. The minimum content was observed in control treatment. The maximum delta-3-caren content (0.97) was found in 50% washed SMC treatment. Moreover, the maximum alpha-terpinene (1.6) was related to 20% washed SMC treatment. In case of p-cymene the maximum content (3.15) was obtained when 30% washed SMC was applied, thirteen times higher than in 50% vermicompost treatment (0.24) and 47% higher than control treatment (2.15).

Since essences are terpenoids compounds and their biosynthesis needs a lot of ATP and NADPH, a considering the role of N and P in their biosynthesis (Loomis and Corteau, 1972), application of vermicompost could increase essence content through increasing N and P availability (Sefidkon *et al.,* 2005). Nitrogen play a critical role in chlorophyll and carbon metabolism enzymes biosynthesis so that nitrogen application improves photosynthesis efficiency in plants. Plants produce more leaves when nitrogen

Table 6- Coefficient correlation of vegetative growth Characteristic and macro elements content in aerial parts of summer savory

	SPAD	Plant dry weight	Leaf area	dry weight	Nitrogen	Phosphorus	Potassium	Calcium
Calcium								1
Potassium	*, ** and ns: significant at 5% and 1% probability level and non- significant, respectively						1	0.530 *
Phosphorus						1	0.503 *	0.374 ns
Nitrogen					1	0.589 *	0.423 ns	0.499 *
dry weight				1	0.489 ns	0.022 ns	0.365 ns	0.370 ns
Leaf area			1	0.511 *	0.565 *	0.424 ns	0.251 ns	0.239 ns
Plant dry weight		1	0.681 **	0.468 ns	0.030 ns	0.164 ns	0.063 ns	0.100 ns
SPAD	1	0.509 *	0.314 ns	0.512 *	0.26 ns	0.281 ns	0.207 ns	0.020 ns

*, ** and ns: significant at 5% and 1% probability level and non- significant, respectively

is sufficient in their growth media. All these factors cause increased photosynthesis efficiency and essence biosynthesis in plants. Therefore, organic fertilizers such as vermicompost increase essence production in plants through increasing nitrogen availability (Nooshkam *et al.,* 2015). In a study (Rezvani-Moghadam *et al.,* 2013) have stated that application of organic fertilizers increases essence content in summer savory plants (Rezvani-Moghadam *et al.,* 2013). Similarly, (Makizadeh Tafti *et al.,* 2012) have reported that chemical and biological fertilizers, containing plant growth promoting bacteria could increase growth parameters and essence content in summer savory plants (Makizadeh Tafti *et al.,* 2012) so that the maximum essence was obtained from integrated treatment. In another study on *(Satureja sahandica)* the maximum alpha-terpinene and gamma-terpinene were reported when 2 ton h^{-1} vermicompost and 40 liter vermi T was applied, in addition, the maximum carvacrol was obtained when 4 ton vermicompost was used (Hossaini *et al.,* 2015). (Anwar *et al.,* 2005) studied the effect of organic fertilizers on basil and reported that the application of 5 and 10 ton ha-1 vermicompost could increase essence content through improving soil physical and biological properties (Anwar *et al.,* 2005). (Darzi and Seyed Hadi, 2015) have stated that application of 10 ton ha-1 vermicompost increases essence percentage and yield in dragonhead (13). Increase in essence content and yield in mint (Kiani *et al.,* 2014), dragonhead (Darzi *et al.,* 2015; Mafakheri *et al.,* 2012) and *Dracocephalum* Neamati *et al.,* 2014) have been previously reported. The current results are in garment with previous findings.

CONCLUSION

In general, the results indicated that application of organic fertilizers could increase growth parameters, essence yield and nutrients uptake in summer savory compared with control treatment. It appears that vermicompost and SMC application, in comparison with control treatment, provide better condition for beneficial microorganisms living in the soil. Among the treatments, vermicompost caused the maximum yield compared with other treatment. In addition, washed SMC showed better effect on studied traits compared with unwashed SMC, which might be due to higher salinity in unwashed SMC.

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