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Original Article

Dry Matter and Essential Oil Yield Changes of *Lavandula officinalis* under Cowmanure and Vermicompost Application

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Abstract

In order to study the effect of organic fertilizer on shoot yield and essential oil content of lavender, this experiment was conducted in the Research Institute of Forest and Rangelands, Karaj, Iran, in 2013-14. The treatment groups consisted of vermicompost (0, 5, 10 and 15 ton/ha) and cow manure (0, 10, 20 and 30 ton/ha). The experimental design was a factorial experiment based on randomized complete block design (RCBD) with three replications. The resultsshowed that cow manureapplication significantly affected big and smallcanopy diameter, canopy perimeter, lateral stems number and woody stem yield ($P\leq 0.01$). Moreover, manure significantly affected main stem diameter and leaf yield ($P\leq 0.05$). Results indicated that vermicompost application significantly affected big and smallcanopy diameter, annual stem number, leaf yield, annual stem yield, woody stem yield, total biological yield, essential oil yield ($P\leq 0/01$), and main stem ($P\leq 0/05$). According to the results, the interaction effect of treatments was significant for total shoot and leaf yield ($P\leq 0/05$). The highest sub stem number (24 n/p) was obtainedin 30 ton/ha manure treatment. While, the highest leaf yield (2206.4 kg/ha), annual stem yield (7133.2 kg/ha), annual branches yield (9933/6 kg/ha), total biological yield (1333.6 kg/ha) and essential oil yield (82.67 kg/ha) were determined at 15 ton/have vermicompost treatment. These fertilizers can improve tiller number and lateral stems growth but not affect essential oil percent and yield. It seems that they can increase it in drought stress condition because of improving soil moisture and fertility.

Keywords: Lavander (*Lavandula officinalis*), Cowmanure, Vermicompost, Essential oil, Dry matter yield

Introduction

Lavandula officinalis Chaix is an evergreen bushy shrub with straight and woody branches, the lower of which are leafless, putting out numerous herbaceous stems to a height of about 1 meter [1,2] *L. officinalis* is a native of Southern Europe and the Mediterranean region [3]. Vegetative body and flowers of lavender are used as medicine. Treatments of some skin diseases such as improving burns, wounds, minor scratches and psoriasis treatment are seen by the plant; Moreover, its oil is recommended for anxiety, restlessness and insomnia [4].

Soils in arid and semi-arid regions of Iran which includes more than 80% of agricultural land, in terms of organic materials are poor. To improve agricultural productivity and soil fertility, it is necessary to add organic matter to the soil [5]. The use of organic matters such as animal manures, human waste, food wastes, yard wastes, sewage sludges and composts have long been recognized in agriculture as beneficial for plant growth and yield and the maintenance of soil fertility. The new approaches to the use of organic amendments in farming have proven to be effective means of improving soil structure, enhancing soil fertility and increasing crop yields. Organic matters are excellent source of plant-available nutrients and

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their addition to soil could maintain high microbial populations and activities [6]. Organic manures have more advantages compared to chemical materials. These participate in nutrient cycle of production of toxin and microbial substances and improve soil physical and chemical characteristics. In a few recent decades, consume of chemical fertilizers in agricultural lands has been caused bio environmental problems such as water source contamination, falling of agricultural crops quality and reduction of soil fertility [7]. Among the organics manure, vermicompost was one of the best organic manure in increasing the crop yield [8]. Vermicompost is applied to the manure that obtains from refuse of special species of earthworm (special species of red worms named *Eiseniafoetida* that are calling tiger worm or composter worm [7]. Vermicompost plays an important role for improving soil physical properties and contains higher levels of relatively available nutrient elements, which are essential for plant growth [9]. Vermicompost is being a stable fine granular organic matter, when added to soil, it loosens the soil and improves the passage to the entry of air. The mucus associated with the cast being hydroscopic absorbs water and prevents water logging and improves water holding capacity. The organic carbon in vermicompost and animal manure releases the nutrients slowly and steadily into the system and enables the plant to absorb nutrients [10]. Earthworm process materials 'casts' contain nutrients in forms easily available to plants [11,12]. The soil enriched with vermicompost provides additional substances that are not found in chemical fertilizers [10]. There is evidence that earthworms produce plant hormones in their secretions [13] which increase the growth and yield of crops [8]. Greenhouse and field studies have examined the effects of vermicompost on cereals and legumes [14], vegetables [15,16] and field crops [17]. Most of these investigations confirmed that vermicomposts have beneficial effects on plant growth [18,19].

Most of research on the use of vermicompost has been on the horticultural crops and a few workers have been reported the use and effects of vermicompost on the field crops and medicinal plants. However, several studies have been reported that vermicompost can increase growth and yield of some medicinal plants such as basil [20], garlic [21], fennel [22] and chamomile [23]. Vermicopmpost had a positive effect on flower yield and essential oil of roman chamomile [24]. Moslemi *et al*. studied the effect of different quantities of vermicompost on yield and yield components of Coriander (*Coriandrum sativu* L.), and find that vermicompost application caused improve in all component of biological yield, 1000 seeds weight, seed yield, plant height, percent and yield of essential oil and had significant effect in comparison with control group. Based on these results, vermicompost had the least influence on shoot number in plant, harvesting index and bearing rate [25]. The highest plant height, flower head diameter, fresh and dry flower yield and essential oil content of *Matricaria chamomile* were obtained by using 20-ton vermicompost per hectare [26]. Sundararasu and Neelanarayanan suggested that vermicompost is more favorable for vigorous production of tomatoes, because vermicompost treated soil showed increase in plant growth, leaves number, flower and fruits compared to control soil. Moreover, significant yield was recorded on vermicompost soil [27]. Azimzadeh reported that Safflower showed better reaction to organic fertilizer in both dry land and irrigated condition [28]. Zariri *et al*. reported that peppermint medical plant showed better reaction to using 10 ton/ha vermicompost, 10 ton/ha urban waste compost and 50 ton/ha farmyard manure [29]. Azimzadeh *et al*. reported that canola showed a better reaction to manure and vermicompost in limited condition of moisture and their replacement possibility in such as these condition with chemical fertilizer considerable [30].

According to medicinal uses of this plant, cow manure and vermicompost role in improving soil fertility, plant growth and yield, the project was done to investigate the effect of different levels of organic fertilizer on shoot yield and essential oil, and determine proper amount.

Material and Method

This project was performed in Research Institute of Forest and Rangelands, Karaj, Iran (Latitude: 35° 38′ N; Longitude: 51°E; Altitude: 1321 meter (m)) in 2013-14. The soil of the experimental region was loamy with pH 7.36 (Table 1). The experimental design was a factorial study, based on randomized complete block design (RCBD) with three replications. Treatments consisted of vermicompostat four levels (v_1= zero, v_2= 5, v_3=10, v_4= 15-ton ha^{-1}) and cow manure at four levels (m= zero, m_2= 10, m_3=20, m_4= 30-ton ha^{-1}). The

distance between replications was 3 m. The length and width of each plot in the order was 3 and 2 m. The distance of plant on row was 60 cm. After disking land, leveling was done and finally the plots were designed. Cowmanure and vermicompot according to mentioned amount broadcasted plot surface and mixed with soil at the depth of 10 cm by labor. Plants for use were lavender annual transplants. First irrigation was done immediate after dibble, henceforth, primary irrigation was done every 3 days and afterward was weekly and the weeds were controlled manually. All necessary cultural practices and plant protection measures were followed uniformly for all the plots during the entire period of experimentation.

Measurements

Data of the canopy perimeter, bigand small canopy diameter, lateral stems number, woody stem yield, stem diameter, annual stem number, leaf yield, total biological yield, essential oil yield were recorded from each treatment. Measurements and samplings were done on the inner five rows in each plot, discarding 50 cm from both ends to avoid edge effects. Three plants were randomly selected for measuring the traits. Drying was at shade and room temperature (25 °C for 120 h). Measuring devices were a meter, a ruler, a verniercaliper and a digital balance. A sample of 60 g of dried leaves and annual stems were crushed and mixed with 900 ml of water in a flask and the water was distilled for 3 h using a Clevenger-type apparatus.

Table 1 Chemical and physical characteristics for soil of experimental field (at the soil depth of 0 to 30 cm).

Texture	pH	EC (ds/m)	Clay (%)	Sand (%)	Silt (%)	SP (%)	N (%)
Loamy	7.36	1.33	16	44	40	24.63	0.08
P (Ppm)	K (Ppm)	Fe (Ppm)	Zn (Ppm)	Cu (Ppm)	Mn (Ppm)	Organic C (%)	Neutralized organic matter (%)
8.2	378.4	7.72	0.5	1.34	17.72	0.8	10.1

Table 2a Variance analysis of manure and vermicompost effect on morphological traits of lavender

Mean squares										
SOV	df	Plant height	Canopy diameter 1	Canopy diameter 2	Canopy perimeter	Main stem diameter	Leaf length	Leaf width	Lateral stem number	Annual stem number
Block	2	2.67ns	92.54**	113.9**	1234.47**	0.03^{ns}	0.06ns	0.026^{ns}	60.63*	12848.97**
Manure (A)	3	2.23ns	152.21**	172.62**	452.01**	0.35*	0.24ns	0.22^{ns}	71.69**	734.66^{ns}
Vermicompost (B)	3	5.22ns	99.64**	100.09**	191.92^{ns}	0.26*	0.26ns	0.17^{ns}	19.34^{ns}	10486.59**
A × B	9	3.95ns	42.54*	41.33^{ns}	82.06^{ns}	0.06^{ns}	0.27ns	0.27^{ns}	36.24*	1941.31^{ns}
Error	30	3.09	16.74	20.62	95.43	0.06	0.24	15.45	12.35	1213.2
CV (%)	-	28.68	10.30	9.86	13.22	16.9	9.83	14.59	16.55	19.02

^{ns}, nonsignificant; *, significant at P≤0.05; **, significant at P≤0.01.

Table 2b Variance analysis of manure and vermicompost effect on dry matter and oil yield of lavender

		Mean squares						
SOV	df	Leaf yield	Annual stem yield	Annual shoot yield	Woody stem yield	Total shoot yield	Oil percent	Oil yield
Block	2	745127.75**	14276352.54**	19774759.5**	72.98*	23993112**	0.03^{ns}	5.85^{ns}
Manure (A)	3	460740.8*	826276.03ns	1703401.16ns	170.97**	4285992ns	0.004^{ns}	1.76^{ns}
Vermicompost (B)	3	1219031.37**	11651543.47**	20371777.93**	307.15**	30990064**	0.006n^{s}	7.0003**
A × B	9	234271.61*	2156970.00ns	2900675.83ns	39.95ns	4026627*	0.02^{ns}	3.99^{ns}
Error	30	105565.63	1347980.1	1570502.6	19.13	1593377	0.02	2.69
CV (%)	-	17.56	19.02	15.75	13.85	14.01	17.02	20.63

^{ns}, nonsignificant; *, significant at P≤0.05; **, significant at P≤0.01.

Table 3a Manure effect on some traits of lavender

Manure (ton/ha)	Plant height (cm)	Small canopy diameter (cm)	Big canopy diameter (cm)	Canopy perimeter (cm)	Main stem diameter (cm)	Leaf length (cm)	Leaf width (cm)	Sub stem number (n/p)	Annual stem number (n/p)
0	57.3a	37b	42.88b	71bc	1.41bc	4.9a	4.9a	18.82c	176a
10	34a	36.2b	42.77b	67.12c	1.31c	4.9a	4.8a	19.74bc	178a
20	34.8a	43a	50.18a	77.5ab	1.58ab	5.1a	4.7a	22.10ab	194a
30	37.5a	42.5a	48.35a	80.3a	1.70a	5.2a	5a	24.26a	185a

Means in a column followed by the same letter are not significantly different (P≤0.05).

Table 3b Manure effect on some traits of lavender

Manure (ton/ha)	Leaf yield (kg/ha)	Annual stem yield (kg/ha)	Annual shoot yield (kg/ha)	Woody stem yield (kg/ha)	Total shoot yield (kg/ha)	Oil percent (%)	Oil yield (kg/ha)
0	2128.2a	5865.4 a	7534.2a	866.4b	8420.6b	0.79a	60.96a
10	1810.6b	5945.2a	7736.7a	874.1b	8610.8b	0.79a	61.69a
20	1791.6b	6453.5a	8246.1a	1002.1b	9266.2ab	0.87a	72.23a
30	1668.b	6151.8a	8280a	1436.6a	9716.6a	0.83a	71.62a

Means in a column followed by the same letter are not significantly different (P≤0.05).

Table 4a Vermicompost effect on some traits of lavender

Vermicompost (ton/ha)	Plant height (cm)	Small canopy diameter (cm)	Big canopy diameter (cm)	Canopy perimeter (cm)	Main stem diameter (cm)	Leaf length (cm)	Leaf width (cm)	Sub stem number (n/p)	Annual stem number (n/p)
0	30.4a	35.96b	43.05b	70.28a	1.31b	4.85a	4.92a		143b
5	35.4a	39.38a	4.63b	70.69a	1.45b	5.08a	4.97a		186a
10	60.08a	40.63a	46.78ab	76.10a	1.59a	5.20a	4.74a		191a
15	37a	42.86a	49.72a	78.34a	1.64a	5.07a	5.02a		214a

Means in a column followed by the same letter are not significantly different (P≤0.05).

Table 4b Vermicompost effect on some traits of lavender

Vermicompost (ton/ha)	Annual stem yield (kg/ha)	Annual shoot yield (kg/ha)	Woody stem yield (kg/ha)	Oil yield (kg/ha)
0	4764.6b	6200.4c	640.4c	54.25b
5	6183.2a	8013.9b	952.7b	62.43ab
10	6335a	8261.2b	1272.4a	67.15ab
15	7133.2a	9339.6a	1333.6a	82.67a

Means in a column followed by the same letter are not significantly different (P≤0.05).

According to Table 3a and 4a, there was no significant statistical difference between two treatments on plant height and mathematically the highest height belonged to vermicompost of 10 ton/ha with 60.8 cm.

Statistical Analysis

Data were analyzed using SAS and means were compared according to the LSD test at 5% probability level**.**

Results

Result of this study indicated (Table 2) that small and big canopy diameter, canopy perimeter, woody stem yield(P≤0.01), main stem diameter and leaf yield (α≤0.05) were different among manure treatments. Moreover, small and big canopy, annual stem number, annual stem yield, annual shoot yield, woody stem and oil yield (α≤0.01), and main stem diameter (α≤0.05) were also significantly affected by using vermicompost. Interaction effect of manure and vermicompost had significant effect on big canopy diameter, lateral stem number, leaf yield and shoot total yield (α≤0.05).

Table 5 Interaction effect of manure and vermicompost on some traits of lavender

Manure × vermicompost	Mean squares			
	Small canopy diameter (cm)	Lateral stem number (n/p)	Leaf yield (kg/ha)	Total shoot yield (kg/ha)
M0V0	32e	12c	981.8e	4807g
M0V5	31.67e	17.61bc	1490.3de	8079def
M0V10	44a-d	11.11ab	2060a-d	9447a-e
M0V15	41a-d	23.8ab	2143abc	11350ab
M10V0	32.55e	17.44bc	1717.7bcd	6403fg
M10V5	35.7de	20.77b	1779.2bcd	9299b-e
M10V10	37.76cde	22.22ab	1507.6de	7916def
M10V15	38.77b-e	18.55b	2161.6ab	10825abc
M20V0	42.94a-d	21.44ab	1532.1cde	8373def
M20V5	43a-d	23.93ab	1777.3bcd	8833cde
M20V10	39.38a-e	19.88b	1682.9bcd	9305b-e
M20V15	46.66ab	23.16ab	2250.2ab	10556abc
M30V0	36.27de	27.7a	1511.6de	7781ef
M30V5	47a	20.88ab	2275.9ab	9656a-e
M30V10	41.73a-d	24.33ab	2454a	11467a
M30V15	45.13abc	24.16ab	2270.9ab	9962a-d

Means in a column followed by the same letter are not significantly different (P≤0.05).

The highest amount of small canopy diameter was observed in M30V5 with 47 cm (Table 5). Manure treatment of 20 ton/ha had the highest amount of big canopy diameter (58.2 cm) and treatment of 20 and 30 ton/ha were in the same statistically group (Table 3a). The highest vermicompost effect on big canopy diameter was observed in 15 and 10 ton/ha with 49.7 and 46.8 cm, respectively (Table 4a).

Using 30 ton/ha of manure fertilizer had the highest canopy perimeter (80.3 cm) among other cow manure treatments (Table 3a). There was no statistically significant difference among vermicompost levels on perimeter canopy but the highest mathematically amount was related to 15 ton/ha with 78.34 cm (Table 4a). The highest amount of main stem diameter was obtained in 30 and 20 ton/ha with 1.7 and 1.5 cm, respectively (Table 3a). The vermicompost treatment of 15 and 10 ton/ha had the highest effect on main stem diameter with 1.64 and 1.59 cm, respectively (Table 4a). Interaction of manure and vermicompost had significant effect on sub stem number (Table 5). M30V0 and M0V0 had the highest (27.7 n/p) and lowest (12 n/p) sub stem number, respectively. However, there was no statistically difference between M30V0 and other treatments (Table 5). Different levels of manure fertilizer showed no significant difference in annual stem number (Table 3a); whereas, application of vermicompost had significant effect on annual stem number compared to control. However, there was no statistical significant difference among vermicompost levels (Table 4a).

According to Table 5, the highest and lowest leaf yield of lavender was obtained in M30V10 (2454 kg/ha) and M0V0 (981.8kg/ha), respectively; although, no significant difference was observed between many of them. There was no significant difference between manure fertilizer levels on annual shoot and stem yield (Table 3b). In vermicompost mean comparison, control treatment with 4764.6 kg/ha had the lowest annual stem yield; whereas 15, 10 and 5 ton/ha vermicompost were in same statistical group and showed the highest amount with 7133.2, 6335 and 6183.2 kg/ha, respectively. The highest and lowest annual shoot yield was observed in 15 (9339.6 kg/ha) and 0 ton/ha (6200.4 kg/ha), respectively (Table 4b). The highest woody stem yield was obtained in 30 ton/ha of manure with 1436.6 kg/ha (Table 3b). Vermicompost mean comparison indicated that 15 (1333.6 kg/ha) and 10 ton/ha (1272.4 kg/ha) had the highest woody stem yield, and the control treatment showed the lowest amount with 640.4 kg/ha. Application 5 ton/ha with significant difference was located between them (Table 4b).

According to interaction effect of cow manure and vermicompost on total shoot yield, the highest and lowest amount were observed in M30V10 (11467 kg/ha) and M0V0 (4807 kg/ha), respectively (Table 5). Manure consumption not significantly affected essential oil percent and yield (Table 3b). But 15 and 0 ton/ha of vermicompost application had the

highest (82.67 kg/ha) and lowest (54.25 kg/ha) effect on oil yield, respectively (Table 4b).

Discussion

Variance analysis of morphological traits indicated (Table 2) that manure and vermicompost fertilizers not affected plant height and it was decreased with manure application (Table 3a). Plant height reduction with manure application can be caused by manure effect on increasing tiller number, lateral stem growth and ultimately canopy transverse growth, and caused by lack complete decay of manure and allocate a portion of soil nutrients (especially nitrogen) as microorganisms food which had acted to decompose manure in soil [31]. Results of this research showed that 10 ton/ha of vermicompost application could improve plant height but it was decreased by increasing up to 15 ton/ha of vermicompost. Increasing plant height in 10 ton/ha may be due to its traits like more pores, ventilation and proper drainage, absorption power and high keep moisture [32]. These traits could improve root environment, better water and nutrient absorption and so make better growth condition for plant. Maybe if harvesting time was delayed, effect of organic fertilizer especially vermicompost was more and better visible. But it seems that lavender could not use vermicompost for increasing plant height due to no fertilizer application by the plant or low fertilizer need and slow growth which need more evaluations.

Increasing canopy diameter and perimeter with manure application revealed that this fertilizer effect on tiller and sub stem number was more than effect on plant height. In addition, manure application caused increased in main stem diameter. Increasing in tiller and sub stem number could be due to genetic and environmental factors. Due to genetically equal plants in the study, we can conclude that increasing in these traits were because of different manure levels consumption. Increasing tiller and shoot number made increase in leaf and stem density. In addition to genetic factor in tiller and sub stem producing, they are influenced by nutritional factors specially balance between elements such as nitrogen, phosphorus and potassium. It has been reported that in manure and vermicompost is a balance in elements liberalization [33]. In a research on *Tagetespatula*, stem diameter increasing in vermicompost usage was reported due to the high cation exchange capacity of vermicompost that made increase in plant growth and canopy diameter [34].

Green manure, compost and animal manure usage lead to increase in organic matter, nitrogen, improve soil structure, increase cation, increase gas exchange and soil microorganism activity [35]; but the effectiveness of these fertilizers depend on plant species, consumption time and strongly type of trait. In our research, manure and vermicompost consumption showed no increasing or decreasing effect on leaf length and width (Table 2, 3 and 4). This may be due to leaves high number, growing, continuous production, limitation on growth, genetic and other unknown factors.

Analysis of variance revealed (Table 2b) that leaf and annual stem yield increased by manure and vermicompost application. Leaf yield was influenced by interaction effect of fertilizer levels. Manure levels with potential in providing nutrients especially nitrogen make increase in the plant vegetative growth and by increasing leaves number make increase in leaf area index [36]. Vermicompost application can stimulate plant vegetative and reproductive growth and cause increased in plant growth due to variety of reasons such as having macro- and micronutrients, protease, amylase, cytokinin and auxin [37]. For the effectiveness of all mentioned factors, not only a trait but also the correlation between them can be very important, and the effect of fertilizer on trait component can be so important and crucial. In this study, shoot yield increasing influenced by its component. Thus increasing in canopy diameter, main stem perimeter and sub stem number by manure application and some of mentioned traits by vermicompost application are main reasons of shoot yield increasing. Similar results on *Hypericum perforatum* has been reported [38]. These researchers expressed yield increasing by combination fertilizer levels due to the effect of them on increasing photosynthetic area. The similar result was observed in our study because leaf yield showed increase.

The interaction effect of fertilizers revealed (Table 5) that it was not significantly affected many of measured traits. So, it can be concluded that lavender need to fertilizers is low. In a trait like leaf, opposite result was observed. Many leaf numbers, its continuous production in growth period, increasing leaf area and respiration increase due to shading could be its reasons [39]. The results revealed that manure and vermicompost application had no effect on oil percent. Some reasons could

cause it such as improving soil structure by these fertilizers, root system development, increasing of water absorption power, regular irrigation, gradual release of elements, no lack of specific elements, prolongation of growth period, no reaching to flowering stage and absence or reduction of environmental stress especially water stress. It has been reported that manure, vermicompost and biological sources application instead of chemical sources could play an important role in keeping of soil biological activity and fertility, increasing agriculture products quality and ecosystem health [40]. Whereas, in some medicinal plants improving soil fertility due to increasing of moisture and microorganisms activity made decrease in environmental stresses and plant quality especially oil percent.No increasing in oil yield under manure consumption could be correlated with lack of increasing in oil percent and annual shoot yield. Results of vermicompost consumption indicated that oil yield was increased and it could be due to its component increasing (oil percent and annual shoot yield).

Conclusion

There is a balance in elements liberalization of cow manure and vermicompost; therefore, these fertilizers consumption could have significant effect on tiller number, production of lateral stems, canopy diameter, main stem diameter, canopy perimeter and shoot yield. On the other hand, these fertilizers improve soil fertility, moisture and microorganism activity and cause decrease in environmental stresses. If they be used in drought condition, can cause increase in oil yield and percent.

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