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Investigation of activated biochar and soil ameliorative effects on *Menthea piperita* L. yield

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Abstract

Menthea piperita from *Lamiaceae* family is one of medicinal plants which is widely used in pharmaceutical, food and hygienic industries. Organic and bio-fertilizers consumption in medicinal plants production and sustainable agriculture is important for achieving high quality of yield, environment protect and society health. Therefore, a experiment was conducted to investigate the effect of organic fertilizers on *Menthea piperita* in the research greenhouse of Islamic Azad University of Karaj, Iran. It was done in randomized complete block design with four replications in the autumn and winter of 2014. Treatments were imposed based on pots volume with vermicompost (5, 15 and 30%), peat moss (70, 85 and 100%), biochar (use or non-use) and mycorrhiza (use or non-use) combination. The analysis of variance indicated that treatments were different for stem fresh weight, leaf fresh weight, weight of total dry matter and shed leaves weight ($\alpha \leq 0.05$), and for root dry weight ($\alpha \leq 0.01$). Different fertilizer treatments had no significant effect on stem, leaf and soot dry weight. The highest leaf fresh yield belonged to 15% of vermicompost, 85% of peat moss, non-use of mycorrhiza and biochar treatment with 39.15 gram per pot. It seems that vermicompost with chemical fertilizers could be increased photosynthesis, dry matter amount, yield and growth of the plant due to supplying its nutrients in absorbable form.

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Introduction

In recent decades and agriculture relied on the chemical inputs to achieve high yield, incorrect and excessive use of synthetic inputs addition to causing major problems and environmental pollution, hinder the achievement of sustainable yield; therefore, the emphasis on reducing energy consumption of inputs, proper management of water, soil, and biological resources and environmental preservation were done to achieve optimal and stable yield (Sokhanchin, 2001). In the soil-plant system, root environment is a gravity center of energy in the soil. Therefore, management change of soil fertility affects agricultural productions and ecosystem stability (Leithy *et al.*, 2006). Organic and bio-fertilizers consumption in medicinal plants production and sustainable agriculture is important for achieving high quality of yield, environment protect and society health (Darzi *et al.*, 2012). According to organic fertilizers especially vermicompost in modifying soil structure and food supply, they naturally have long-term effects and reduce the problems caused by improper use of chemical fertilizer. Khorshidi *et al.* (2013) studied the effect of vermicompost and mycorrhiza on thyme and found that 10 ton/ha of vermicompost, combination 5 ton/ha and inoculation with mycorrhiza fungi had the highest fresh weight, dry weight of bush and dry matter yield. According to reviews on streptomyces and different vermicompost amount on yield and oil of *Menthea piperita* under field condition, 2 ton/ha of vermicompost with 4 ton/ha streptomyces significantly increased mint yield (Dalvand *et al.*, 2011). Behrozfar *et al.* (2013) research revealed that vermicompost consumption had positive effect on fresh and dry weight of aerial organs of basil.

Mycorrhiza has symbiosis living with roots and both of them (plant and fungi) benefit from this life; the plan takes stored food of fungi and it receive nutrients from its host's roots. Mycorrhiza has several functions that each of them are useful for farmers: they can make spread of rot zone and enter to small pores of soil, make nutrients dissolve from mineral such as phosphorus and transfer them to the plant, fortify soil texture and improve it, maintain soil moisture and finally increase water holding capacity in the plant (Khorshidi *et al.*, 2013). Vinutha (2005) reported that basil inoculation with different species of azotobacter and glomus caused increase in biomass weight, growth speed and volatile oil amount. Kapoor *et al.* (2004) observed that fennel inoculation with mycorrhiza significantly increased volatile oil yield, umbels number per plant, dry matter and percentage of root symbiosis. Moreover, they found that root symbiosis of fennel with *Glomus fasiculatum* and *G. macrocrpum* significantly increased phosphorous concentration of seed. Joshee *et al.* (2007) reported root inoculations of Scutellaria integrifolia with mycorrhiza not only were effective in plant growth and proliferation especially roots but also increased plant ability for growth in marginal soils with phosphorus deficiency. Gupta *et al.* (2002) found that mint inoculation with *Glomus fasiculatum* increased nitrogen, phosphorous and potassium absorption and product yield in comparison with non-inoculated plants. *Origanum vulgare* inoculation with *Glomus mosseae* revealed that phosphorus concentration in the leaves of this plant significantly increased compared with control treatment. Aliabadi-Farahani *et al.* (2008) reported that coriander inoculation with *Glomus hoi* had the highest biological yield, flowering shoot yield, volatile oil yield of flowering shoot, yield and root length. Biochar is a solid material which obtained from biomass carbonization; it is possible to add to the soil for improving soil efficiency and emissions reduction. It naturally reduces greenhouse gases, cause sediment and discharge atmospheric carbon. In this case, additional carbon dioxide absorb with plants aerial and underground organs, alga, etc. to reduce the adverse effect of global warming phenomenon. Thus, agricultural waste have been transform into soil enhancer which can hold carbon; and in this way help to enhance food security and increase soil biological diversity (Rabie *et al.*, 2013). Peat moss are classifying in different colors, textures and genders. Most of peat mosses have low weight and absorb water up to 20 times their weight but the speed of water loss is too high. They have acceptable water holding and food capacity. There is two kind of peat moss: white (in fact light brown) and black. They have different pH and located in the natural range and slightly lower from nature to acidic. Peat mosses have high cation exchange capacity and low Ec (0.5 Ds/m) (lemaire *et al.*, 1998).

Menthe piperita from *Lamiaceae* family is one of medicinal plants that is widely used in pharmaceutical, food and health industries. It is a hybrid species from crosses between *Menthea aquatic* × *Menthea spicata* (Gardiner, 2000). Its medicinal use include: pain relief of irritable bowel syndrome, carminative, effect on breathing, treatment of whooping cough, anti bacterial and anti fugal properties. Mint effectiveness has been attributed to its volatile oil (which is part of secondary metabolites); therefore, every factor which affects quality and quantity of volatile oil is considered (Niakan *et al.*, 2003). This project was conducted with aimed at improving soil substrate for growth, better yield by increasing water holding quality, reduction of greenhouse gases emission, soil acidity reduction and increasing carbon amount.

Material and methods

Experiment location

This study was conducted with the aim of achieving to the best culturing substrate of *Menthe piperita* in the research greenhouse of Islamic Azad University of Karaj, Iran in autumn and winter of 2014. It was done in randomized complete block design with four replications. Defined treatments were imposed based on pot volumes with vermicompost, peat moss, biochar and mycorrhiza (Table 1).

Pots and cuttings propagation

Some physical and chemical properties of vermicompost (Table 2) and peat moss (Table 3) were analyzed to determine their nutrient amount. Initially, pots volumes were calculated and the bed contents were mixed according to Table 1. After filling the pots, four same and rooted cuttings of *Menthe piperita* were planted in each pot. Irrigation was done immediately after planting. During growth period, it was done three times a week with rainy method and shed leaves were calculated and weighted after drying. The plants were harvested at flowering stage.

Measured traits and statistical analysis

Evaluated traits included: stem fresh weight, leaf fresh weight, stem dry weight, leaf dry weight, shoot dry weight, biological yield, shed leaves weight (by using digital scale) and percent (numeration). Data were analyzed by using SAS software and statistical comparison with Duncan's multiple range tests.

Results and discussion

Variance analysis indicated that treatments significantly affected stem fresh weight, leaf fresh weight, total dry matter weight, shed leaves weight ($\alpha \leq 0.05$), and dry weight of root ($\alpha \leq 0.01$). None of used treatments showed significant effect on stem, leaf and shoot dry weight (Table 4).

According to mean comparison (Table 5), the highest stem fresh weight was observed in 15% of vermicompost, 85% of peat moss, non-use of biochar and mycorrhiza combination with 78.1 gram per pot. The lowest stem fresh weight belonged to 30% of vermicompost, 70% of peat moss, use of biochar and non-use of mycorrhiza with 45.83 g/per pot. 15% of vermicompost, 85% of peat moss, use of biochar and mycorrhiza showed the highest leaf fresh weight (39.15 g/per pot).

The highest root dry weight was observed in 15% of vermicompost, 85% of peat moss, use of biochar and mycorrhiza with 4.93 g/per pot. The lowest root dry weight belonged to two treatments (30% of vermicompost, 70% of peat moss, use of mycorrhiza and non-use of biochar, and 30% of vermicompost, 70% of peat moss, use of biochar and mycorrhiza) with 0.67 g/per pot. 15% of vermicompost, 85% of peat moss, use of biochar and mycorrhiza revealed the highest weight of total dry matter and shed leaf weight with 17.2 and 6.37 g/per pot, respectively.

Table 1. Used treatment.

Number code	Treatments	Vermicompost %	Peat %	Mycorrhiza	Biochar
1	a	0	100	NO	NO
2	b	15	85	NO	NO
3	c	30	70	NO	NO
4	d	0	100	YES	NO
5	e	15	85	YES	NO
6	f	30	70	YES	NO
7	g	0	100	YES	YES
8	h	15	85	YES	YES
9	i	30	70	YES	YES
10	j	0	100	NO	YES
11	k	15	85	NO	YES
12	l	30	70	NO	YES

Table 2. analysis result of used vermicompost.

EC ds.m (1:5)	pH (1:5)	Moisture	O.C (%)	O.M (%)	C/N	K_2O (%)	K(%)	P_2O_5
7.5	7.6	4.06	22.89	40.19	13.89	0.66	0.55	0.98
Pb (mg/kg)	Cd (mg/kg)	Zn (mg/kg)	Cu (mg/kg)	Mn (mg/kg)	Mg (%)	Ca (%)	P (%)	N (%)
21.8	1.2	205.9	32.7	315	1.16	9.7	0.43	1.64

According to variance results (Table 4), there was significant effect between treatments on stem fresh weight, leaf fresh weight, weight of total dry matter, shed leaf weight and root dry weight but there was no significant effect on leaf, stem and shoot dry weight.

No significant difference on dry weight of various organs is in contrast with other researchers' findings; it could be due to more irrigation, test execution in greenhouse condition, fertilizer rejection of the plant, experiment conducting for one year and other results.

Table 3. Analysis result of used peat moss.

Element	N	Ammonium	P	P_2O_5	K	K_2O	Mg	MgO	B	Mo	Cu	Mn	Zn
(g/m^3)	70	50	60	140	200	240	13	21	1	4.6	8.3	5	3.2

Table 4. Variance analysis of vermicompost, peat moss, biochar and mycorrhiza effect on measured traits.

SOV	df	Mean squares							
		Stem fresh weight	Leaf fresh weight	Stem dry weight	Leaf dry weight	Shoot dry weight	Root dry weight	Weight of total dry weight	Shed leaves weight
Block	3	314.26ns	74.22ns	0.01ns	0.05ns	0.04ns	0.5ns	0.2ns	0.31ns
Treatment	11	425.78*	193.01*	0.13ns	0.16ns	0.27ns	1.54**	1.66*	0.98*
Error	33	267.24	48	0.14	0.21	0.34	0.21	0.4	0.35
CV (%)	-	26.9	25.47	17.68	19.19	18.08	29.57	17.21	26.4

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

In a study on mycorrhiza and vermicompost effect on thyme herb (Khorshidi *et al.*, 2013), 10 ton/ha of vermicompost and combination treatment of mycorrhiza inoculation and 50 ton/ha of vermicompost had the highest bush fresh yield, bush dry yield and dry weight yield that showed lack of consistency with our results. Dalvand *et al.* reported that 2 ton/ha of vermicompost with 4 ton/ha streptomyces consumption in field condition increased significantly volatile oil percent, volatile oil yield and mint yield. 5 ton/ha of vermicompost with chemical fertilizers increased yield and growth of basil herb due to desirable effect of vermicompost in supplying plant nutrients in absorbable form. This means that the fertilizer particles form complexes with soil nutrients especially metallic elements because of high specific surface and having different organic combination in their surface which are easily absorbable for the plant (Anwar *et al.*, 2005). According to Mohammadi *et al.* (2012) report about 10, 20 and 30 ton/ha of vermicompost effect on *Cuminum cyminum* L., consumption of suitable vermicompost amount increased photosynthesis and dry matter amount due to improving soil microbial activity, producing plant growth regulators by these organisms and providing more nutrient absorption.

Table 5. Mean comparison of vermicompost, peat moss, biochar and mycorrhiza effect on measured traits.

Treatment code	Stem fresh weight (g/per pot)	Leaf fresh weight (g/per pot)	Stem dry weight (g/per pot)	Leaf dry weight (g/per pot)	Shoot dry weight (g/per pot)	Root dry weight (g/per pot)	Weight of total dry weight (g/per pot)	Shed leaves weight (g/per pot)
$V_0P_{100}M^-B^-$	63.27abc	25.76b	5.41a	6.15a	11.56a	3.93a	15.5ab	3.9ab
$V_{15}P_{85}M^-B^-$	78.1a	39.15a	4.13a	6.35a	10.48a	1.07bc	11.55ab	4.82ab
$V_{30}P_{70}M^-B^-$	61.34abc	29.82ab	5a	6.42a	11.43a	2.78abc	14.21ab	4.25ab
$V_0P_{100}M^+B^-$	64.83abc	24.44b	4.36a	5.63a	10a	4.06a	14.05ab	2.92ab
$V_{15}P_{85}M^+B^-$	77.47ab	31.7ab	5.88a	7.28a	13.16a	4.02a	17.18a	3.37ab
$V_{30}P_{70}M^+B^-$	50.05bc	23.23b	4.41a	4.98a	9.4a	0.67c	10.06ab	2.2b
$V_0P_{100}M^+B^+$	68.51abc	26.21b	5.57a	7.6a	13.18a	3.83a	17.01a	4.52ab
$V_{15}P_{85}M^+B^+$	57.72abc	24.18b	4.9a	7.37a	12.27a	4.93a	17.2a	6.37a
$V_{30}P_{70}M^+B^+$	50.22bc	22.7b	3.27a	4.36a	7.63a	0.67c	8.31b	3.1ab
$V_0P_{100}M^-B^+$	54.98abc	24.73b	3.54a	5.18a	8.72a	4.54a	13.27ab	1.65b
$V_{15}P_{85}M^-B^+$	56.72abc	30.62ab	4.94a	6.61a	11.55a	3.5ab	15.06ab	4.8ab
$V_{30}P_{70}M^-B^+$	45.83c	23.68b	4.3a	5.34a	9.63a	1.03bc	10.67ab	2.95ab

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

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