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The Effect of Different Compost Compositions on Arbuscular Mycorrhizal Colonization and Nutrients Concentration of Leek (*Allium Porrum* L.) Plant

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ABSTRACT

Plant residue material produced compost is an organic fertilizer source and it is commonly used for soil amendments. Also in order to reduce the amount of chemical fertilizers need mycorrhizal inoculation can be used as an agricultural strategy. Thus, the aim of the research is to examine the effect of several residue materials produced compost and mycorrhizae fungi with two growth media on leek plant growth, nutrient uptake, and mycorrhizae spores' production.

Eight different row organic materials and animal manures were used as compost production during 8 months. Leek (*Allium porrum* L.) plants were inoculated with *Funnelformis mosseae* and *Claroideoglossum etunicatum* with a level of 1000-spore per pot. The leek plant was analyzed for determination of nutrient concentration, root colonization, spore production, and shoot/root dry weight.

The composts were made from domestic waste, animal manure (bovine animal), animal manure (ovine animal), and different plant materials were determined to be the most suitable compost material for plant growth and mycorrhizal spore production compared to the rest of compost material. Mycorrhizal inoculation significantly increased leek plant growth and nutrient uptake especially phosphorus (P), potassium (K), copper (Cu) and zinc (Zn). Plants grown in 5:3:2 (volume/volume) growth media was responded better to the mycorrhizal inoculation than grown in 1:1:1 (v/v) growth media. *Funnelformis mosseae* inoculated plants have higher plant growth and nutrient uptake than that of *Claroideoglossum etunicatum* inoculation.

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Compost; mycorrhizal inoculation; nutrient uptake; leek plant; mycorrhizae spore production

Introduction

Increasing world population raises the demand for food and its safety (Ortas and Lal 2012). The concern of growing food supply with decreasing unsafe farm practice requires the development of new research areas and techniques. One of the most promising mechanisms for safe food production is applying bio-inoculants and organic fertilizers. Currently, agricultural products are done under high usage of chemical fertilization. The use of fertilizers, which are obligatory for vegetable production, and combining them with organic resources, are suitable in accordance with ecological principles and commercial practices. Composting of organic, domestic and urban wastes and reuse of them in agricultural production now are a popular and achievable implementation.

The usage of mycorrhizae also has a great significance in natural farm plant production strategy. The application of different compost materials as a growing medium (GM) in mycorrhizal production may

have a profound effect on the success of organic farming. Intensive tillage is causing deterioration of soil structure and has a negative effect on soil organic matter content, moreover, widely applying commercial fertilizers are bringing the environmental issue, such as soil and water pollution. Trend of soil organic matter decrease may be reinforced by laborious carbon sequestration techniques and organic fertilizer application, which is leading the agriculture system to reconsider a plant production methodic and economic costs. For those reasons, composting and application of waste organic materials may have a potential role in increasing the soils organic matter and consequently have effects on food security. At the same time, application of compost in long-term experiments showed that improvement of soil properties as well as an increase in plant productivity (Ortas, Akpinar, and Lal 2013).

Composting in organic farming is the one of major nitrogen source for plants nutrition (Nelson and Janke 2007). Compost application is expected to be more effective when applied along with mycorrhizal inoculation. Composting provides mineral nutrients to the soil (Tejada et al. 2001; Zheljazkov and Warman 2004) for better plant production. It has been reported that compost has a positive effect on beneficial soil organisms and decreases plant pathogens and at the same time increases the water holding capacity of the soil (Wells, Chan, and Cornish 2000). (Ortas and Ustuner 2014a, 2014b) found that compost containing different growing media increased the growth and nutrient content of citrus plants. Roy and Hore (2011) also reported that applied *Azospirillum*, arbuscular mycorrhizal (AM) fungi and four different compost combinations were compared to inorganic fertilizer, and reported that the highest yield was gained under application of Vermicomposting + AM + *Azospirillum* in turmeric plant grown between palm plantations in their study.

Mycorrhizal root colonization can be effective in a way to supply host plant mainly with phosphorus (P), copper (Cu) and zinc (Zn) and other nutrients (Cameron 2010; Marschner 2012; Ortas 2012; Smith and Read 2008). Studies in organic farming have shown that AM fungi increase microbial activity and root exudates, thereby increasing plants P uptake from the less fertile soils (Nelson and Janke 2007). Recently, various techniques have been used to produce mycorrhizae spores (Akpinar, Ortas, and Demirbas 2018). Diversity of AMF (Arbuscular Mycorrhizal Fungi) species have been tested with different soil and substratum, soilless culture methods and in vitro propagation methods (Ijdo, Cranenbrouck, and Declerck 2011). Mycorrhizal spores production required controlled greenhouse conditions and it is particularly important to select the appropriate temperature, moisture and the suitable host plant (Douds et al. 2006; Douds Jr. et al. 2005). Onion and leek (*Allium* spp.), Maize (*Zea mays* L.) and Bahia grass (*Paspalum notatum* Flugge) are widely used in the production of mycorrhizal spores (Ijdo, Cranenbrouck, and Declerck 2011).

The most common cultivation mediums are soil, sand (Douds and Schenck 1990), torf (Ma, Yokoyama, and Marumoto 2007) and compost (Douds Jr. et al. 2005). For the purpose to obtain clean fungal materials may be used the addition of river sand to growing medium (Chen, Christie, and Li 2001; Neumann and George 2005). Also, authors mentioned that in mycorrhiza production what compost and other organic substances (such as peat-based) may be added to the growing media, to the aim is to cover the nutrient deficiencies (Gaur and Adholeya 2000; Ma, Yokoyama, and Marumoto 2007).

Future agricultural policies are focusing on safe food production processes, environment-friendly techniques for sustainable agricultural practices. Compost production and AMF are some of the natural resource which can help to achieve these goals. Our hypothesis is different compost material prepared growth media to have an effect on plant growth and mycorrhizal spore production. The aim of this study was to determine the effects of mycorrhizal spore production on host leek plant growth and nutrient uptake under different mixing composts with various ratios and two growth media.

Materials and methods

The experiment was carried out under controlled greenhouse conditions with completely randomized and three replicates.

Eight different wasting raw materials were used to produce composting materials such as;

I: Compost prepared with leaves (50%), fruits (50%) belonging to different citrus plants

II: Compost prepared with various fruit and vegetables wastes from the local market place

III: Compost prepared from domestic wastes (domestic food waste)

IV: Compost prepared from animal manure (bovine manure (50% manure, 50% wheat stalk)

V: Compost prepared from animal manure (ovine manure (50% manure, 50% wheat stalk)

VI: Compost prepared from a mixture of green plant materials (maize (25%) and clover (25%)) and wheat straw (50%)

VII: Compost prepared from material collected from forest residue (Mulberry, Cypress, Pine needle, Cyprian Akasia, Poplar)

VIII: Compost prepared from leaves of palm and leguminous trees (Harnup, Leucaena)

The most important criterion for selecting and preferring the compost materials was in abundance and availability in the region.

Preparation of composting

For preparing compost, 120 cm high and 80 cm wide wire cages were used. A straw layer was laid under the cages, and the organic material collected for composting is placed in layers of 25–30 cm thick, after each layer, small amount of soil was sprinkled on it. Finally, the height of the pile of organic material placed in this way has not exceeded 1 m and then the top of the pile again was covered with a thin layer of soil. Composting process continued during 8 months. During the composting period, the compost pile was lifted 3 times to provide ventilation. For each ton of dry material 20 kg of ammonium sulfate and 7 kg of superphosphate were used to speed up the composting process. To ensure optimal decomposition conditions, water content in the compost pile mass should be approximately 60%. Regular mixing and maintenance were carried out to keep the temperature between 55°C and 65°C.

Growing media

Two growing media (GM A) were prepared in following ratios 1:1:1 (Compost: Soil: Sand v/v) and GM B, was prepared 5:3:2 ratio of andesitic tuff: Soil: Compost v/v: The leek seeds (Inegol seeds) were grown in small plug trays cell and then seedlings were transferred to the pot. In the study, plastic pots with a capacity of 3 kg were used and five seeds were planted at the beginning of each pot. After germination, they were reduced to three plant. Leek plants were grown in a greenhouse at 25–28°C and a relative humidity of 70–80%.

Sterilization of growing medium and pots

The sterilization of the growing media was carried out by autoclaving at 120°C for 2 h with a shock effect, in order to eliminate the indigenous mycorrhizae spores. The autoclaved growing medium was kept in polyethylene bags until used in the pot experiment (about 3 weeks).

Plant material and mycorrhiza application

Leek (*Allium porrum* L.) were used as host plants with high mycorrhizal dependence (Ortas 2008). *Funneliformis mosseae* (Nicolson and Gerdemann) Rothamsted isolate, UK); *Claroideoglossum etunicatum* ((Becker and Gerdemann) Nutri-Link isolate; USA mosseae) were used as a mycorrhiza spores. Mycorrhizae inoculum was placed approximately 50 mm below the seedling roots.

Plant and soil analysis

Compost and plant samples were ashed at 550°C for elemental determinations and then phosphorus was calorimetrically analyzed by spectrophotometer (Murphy and Riley 1962), K, Fe, Mn, Zn, and Cu concentration were determined by ICP. Compost burning loss, pH and salinity were measured. Nitrogen and carbon analysis were carried out according to the method of dry combustion by Grant et al. (2001).

Isolation of mycorrhizal spores and root colonization

The wet sieving method was used for the isolation of pure spores (Gerdemann and Nicolson 1963); Root clearing and staining process was done according to Koske and Gemma (1989) and mycorrhizal root colonization was determined by using the gridline-intersect method Giovannetti and Mosse (1980).

Statistical analysis

The experimental design which was three factors: compost type (8), mycorrhizal type (3), and growth media types (2). The variations in plant growth parameter were assessed via the analysis of variance ANOVA (Multanova test) procedure using the SPSS 20.0 computer program. The main last significant effects were determined Tukey test at $P < .05$.

Results and discussion

The temperature was measured once a month during the composting process. The temperature of the materials reached 60°C in the first 2 months and then fell up to the 12–16°C after several months. In the composting process, the temperature of the materials in the first 1-month period has reached up to 60°C and the temperatures have decreased after 12–16°C (Table 1).

Some chemical properties of the obtained compost materials are presented in Table 2. The pH of the composts varies in between 7.15 and 7.66. Salinity measurement determined that all composts materials are non-saline except domestic food waste made compost have highest 0.807 mmhos/cm salts. The finding results are parallel with Brinton (2003) results in the present experiment.

The highest P concentration was determined as 0.56% in compost prepared with animal manure fertilizers. The lowest concentration of P was found to be 0.26% in compost I, (50% leaf of different citrus plants, compost prepared with 50% fruit). The highest K content (0.49%) was determined in compost V which was prepared with animal feed (50% animal feed, 50% wheat stalks) concentration of Fe and Mn

Table 1. Temperature measurements during the composting process.

	18.06.2012	19.07.2012	15.08.2012	27.09.2012	16.10.2012	18.11.2012	17.12.2012	12.01.2013
	°C							
I	40	54	52	44	33	26	15	16
II	47	53	48	37	31	19	15	14
III	49	51	44	41	37	26	13	12
IV	41	59	48	40	39	28	13	13
V	50	60	51	44	36	31	13	14
VI	54	59	56	46	35	28	14	15
VII	44	58	47	39	32	26	14	13
VIII	41	56	53	40	29	24	15	16

I: Compost prepared with leaves (50%), fruits (50%) belonging to different citrus plants

II: Compost prepared with various fruit and vegetables wastes from the local marketplace

III: Compost prepared from domestic wastes (domestic food waste)

IV: Compost prepared from animal manure (bovine manure (50% manure, 50% wheat stalk)

V: Compost prepared from animal manure (ovine manure (50% manure, 50% wheat stalk)

VI: Compost prepared from a mixture of green plant materials (maize (25%) and clover (25%)) and wheat straw (50%)

VII: Compost prepared from material collected from forest residue (Mulberry, Cypress, Pine needle, Cyprian Akasia, Poplar)

VIII: Compost prepared from leaves of palm and leguminous trees (Harnup, Leucaena)

Table 2. Some chemical properties of different compost materials.

	pH	Salinity (mmhos/cm)	P %	K %	Fe	Mn	Cu	Zn	C %	N %	C/N
I	7.45	0.478	0.26	0.25	2692	303.9	8.2	28.8	9.55	0.60	15.8
II	7.45	0.491	0.25	0.44	3086	296.2	10.8	29.9	7.77	0.52	14.9
III	7.66	0.807	0.29	0.33	3224	307.9	8.5	29.2	8.05	0.54	15.0
IV	7.47	0.310	0.56	0.22	2199	289.5	11.6	80.8	15.37	1.25	12.3
V	7.73	0.323	0.37	0.49	2907	265.7	11.5	55.3	13.28	1.11	12.0
VI	7.49	0.376	0.29	0.28	2596	257.2	7.7	41.6	10.10	0.72	14.0
VII	7.38	0.229	0.35	0.30	2723	303.0	10.6	56.4	9.75	0.68	14.4
VIII	7.15	0.749	0.37	0.30	2558	281.0	7.6	35.1	7.90	0.60	13.2

were relatively high and showed the compost is rich in microelements. The highest Zn (80.8 mg kg⁻¹) concentration similar to the P % concentration are determined in compost IV (Table 2). Similarly, Shah, Jani, and Khan (2014) found that the highest Zn concentration among the different composts they made was 82.4 mg kg⁻¹ in the compost made from bovine residue. Compost made in bovine manure (50% manure, 50% wheat stalk and ovine manure (50% manure, 50% wheat stalk) have high carbon (C) and nitrogen (N). The C/N ratios were also determined and it has found that the composts results vary between 12.0:1 and 15.8:1. In generally the results indicated that nutrient content of composts varies with the nature of the added organic waste materials. In the study of rural and sewage wastes composting found that the C/N ratio of composts varied between 5.5% and 13.4% (Shyamala and Belagali 2012).

After composting process was completed two growth media (GM) were prepared to produce mycorrhizae spore on the leek host plant. GM A consist of soil: sand: compost (1:1:1 v/v) and GM B, consist of andesitic tuff: soil: compost (5:3:2 v/v) and mycorrhizal application was conduct for leek plant growth. At harvest, dry weight of the shoot and root were determined.

In general, the mycorrhizal effect and growing media were statistically significant ($P < .001$) on the dry weights of the shoot and root parts of leek plants (Table 3). Statistically, GM and compost were significantly ($P < .001$) inoculated plant growth as well.

The highest shoot dry matter production was observed as 5.44 g pot⁻¹ in the compost III used GM A with *Fu. mosseae* inoculation and 7.42 g pot⁻¹ in the compost IV used GM B5:3:2 (v/v) growing media inoculated with *Fu. mosseae* (Table 3). However, the highest dry weight of leek roots production 0.80 g pot⁻¹ was observed in compost II used GM A without mycorrhizae, meanwhile in the compost IV used GM B the highest root dry matter production 0.96 g pot⁻¹ was observed under *Fu. mosseae*. Previously Hameeda et al. (2007)'s study showed that mycorrhizal inoculation, vermicompost, and rice derived compost amendment increased the biomass of sorghum (*Sorghum bicolor*) plants. GM B was determined to be the best growing media for dry matter production in both shoot and root parts of leek plants.

The effects of different composting composition on mycorrhizal root colonizations and spore production of leek host plants in different growing environments are shown in Table 4. Mycorrhiza inoculation significantly increased root colonization. Plant grown in GM A have high root colonization than that grown in GM B. The compost I prepared GM A + *Fu. mosseae* inoculation has the highest root colonization (73%). Compost may positively affect the development of mycorrhizal colonization and development as well. Similarly, Muthukumar and Udaiyan (2000); Albertsen et al. (2006); Ustuner et al. (2009); Gryndler et al. (2009) have reported that organic matter increased the root colonization. In the GM B, the higher root colonization rates were detected under *Fu. mosseae* inoculation (57%). Because of the sterilization of the media and the absence of mycorrhiza in control applications was observed, except for several control composts, which may be from cross contamination.

Mycorrhizal spore's production was also examined. It was determined that the number of spores in the control plants due to sterilization in both growing media was negligible. The highest spore production was detected under *Cl. etunicatum* inoculation amended with compost VIII prepared GM A medium (108 spores 10 g GM⁻¹) (Table 5). In the GM B, the highest spore production similarly was found under *Cl. etunicatum* and compost VI (114 spores 10 g GM⁻¹). It was reported

Table 3. Under two growth medias conditions the effect of different compost and mycorrhiza on dry weights of top and root parts of leek plant.

		1:1:1*		5:3:2		1:1:1		5:3:2	
		Shoot Dry Weight (SDW)				Root Dry Weight (RDW)			
		g pot ⁻¹				g pot ⁻¹			
Control	I	1.47	±0.80 c	3.36	±1.27 ab	0.68	±0.11 ab (2.2)**	0.88	±0.24 ab (3.8)
	II	2.21	±0.98 a-c	3.22	±1.66 ab	0.80	±0.13 a (2.8)	0.89	±0.13 ab (3.6)
	III	2.53	±0.40 a-c	3.68	±1.46 ab	0.67	±0.11 ab (3.8)	0.83	±0.20 ab (4.4)
	IV	3.10	±0.26 a-c	2.99	±0.29 b	0.74	±0.18 a (4.2)	0.79	±0.09 ab (3.8)
	V	2.17	±1.23 a-c	2.80	±0.53 b	0.63	±0.29 ab (3.4)	0.63	±0.02 ab (4.5)
	VI	2.66	±1.41 a-c	3.59	±0.12 ab	0.78	±0.21 a (3.4)	0.78	±0.11 ab (4.6)
	VII	2.14	±1.24 a-c	3.17	±0.89 b	0.55	±0.17 ab (3.9)	0.81	±0.18 ab (3.9)
	VIII	1.64	±0.65 bc	3.15	±0.79 b	0.47	±0.17 ab (3.5)	0.75	±0.23 ab (4.2)
		2.24 B***		3.24 B		0.67 A		0.80 A	
<i>Fu. mosseae</i>	I	1.82	±0.31 bc	3.42	±1.07 ab	0.49	±0.08 ab (3.7)	0.55	±0.09 ab (6.3)
	II	2.92	±0.48 a-c	3.94	±0.78 ab	0.54	±0.05 ab (5.4)	0.63	±0.21 ab (6.3)
	III	5.44	±2.68 a	3.85	±1.20 ab	0.39	±0.07 ab (13.8)	0.50	±0.08 ab (7.7)
	IV	5.07	±2.02 ab	7.42	±3.57 a	0.60	±0.13 ab (8.4)	0.96	±0.34 a (7.7)
	V	3.60	±1.47 a-c	3.34	±2.30 ab	0.41	±0.06 ab (8.7)	0.58	±0.06 ab (5.7)
	VI	2.45	±0.52 a-c	5.54	±2.28 ab	0.46	±0.17 ab (5.3)	0.75	±0.09 ab (7.4)
	VII	2.49	±0.31 a-c	4.90	±0.66 ab	0.43	±0.02 ab (5.8)	0.68	±0.08 ab (7.2)
	VIII	1.73	±0.32 bc	3.19	±0.22 ab	0.30	±0.01 b (5.7)	0.69	±0.14 ab (4.6)
		3.19 AB		4.45 A		0.45 B		0.67 B	
<i>Cl. Etunicatum</i>	I	2.35	±0.14 a-c	2.61	±0.06 b	0.52	±0.10 ab (4.5)	0.59	±0.20 ab (4.4)
	II	2.83	±0.81 a-c	2.09	±0.89 b	0.64	±0.15 ab (4.4)	0.52	±0.03 ab (4.0)
	III	2.21	±0.36 a-c	2.88	±0.46 b	0.44	±0.10 ab (5.0)	0.68	±0.15 ab (4.2)
	IV	2.00	±0.40 a-c	3.12	±0.43 b	0.46	±0.09 ab (4.3)	0.68	±0.18 ab (4.6)
	V	3.08	±1.28 a-c	3.31	±1.66 ab	0.42	±0.04 ab (7.3)	0.55	±0.02 ab (6.0)
	VI	2.77	±0.51 a-c	3.13	±1.40 b	0.47	±0.17 ab (5.9)	0.42	±0.11 b (7.5)
	VII	3.98	±2.23 a-c	3.56	±1.34 ab	0.51	±0.08 ab (7.9)	0.51	±0.13 ab (7.0)
	VIII	3.87	±1.15 a-c	2.37	±0.80 b	0.53	±0.12 ab (7.3)	0.45	±0.05 b (5.3)
		2.89 AB		2.89 B		0.50 B		0.55 C	
Average		2.77 B****		3.53 A		0.54 B		0.67 A	
Significancy	df								
Growing Media (G)	1	<0.001		<0.001		<0.001		<0.001	
Mycorrhiza(M)	2	<0.001		<0.001		<0.001		<0.001	
Compost (C)	7	0.017		0.017		0.004		0.004	
G X M	2	0.036		0.036		0.023		0.023	
M X C	14	0.016		0.016		0.228		0.228	
G X C	7	0.602		0.602		0.488		0.488	
G X M X C	14	0.246		0.246		0.244		0.244	

Mean of three replicates and ± is a standard error

*1:1:1 (Compost: Soil: Sand v/v), 5:3:2 (Andesitic tuff: Soil: Compost v/v)

**Shoot dry weight/root dry weight

*** Statistical difference between mycorrhizal applications

**** Statistical difference between growing media

previously, compost applications increase sporulation of arbuscular mycorrhiza (Habashy, Abou El-Khair, and Zaki 2008; Olsson et al. 1999). Statistical differences in between growing media determined that leek plant provide more effective root colonization and more spores in the 1:1:1 (v/v) growing media and mycorrhizal root colonization had a statistically significant effect on spore production ($P < .001$) (Table 4). Similarly, Douds, Nagahashi, and Hepperly (2010) reported that compost application increased mycorrhizal spores under field conditions.

Mycorrhizal fungi generally increases the P availability in the soil as well as the P absorption by hyphae (Ortas et al. 2011; Sharif and Claassen 2011; Smith and Read 2008). In non-mycorrhizal plants, the P concentration was generally lower than 0.20% (Table 5). The concentration of P in the tissues of mycorrhiza inoculated plants determined as above the critical value of 0.20% P (Jones 1998). Although it was not significantly different between mycorrhizal species applications, the highest P concentration 0.33% was measured under *Fu. mosseae* inoculated and compost VI prepared GM A. The highest P concentration (0.34%) was obtained in the GM B prepared with compost I and inoculated *Fu. mosseae*

Table 4. Under two growth medias conditions the effect of different compost and mycorrhiza on root colonization and spore production of leek plant.

		1:1:1		5:3:2		1:1:1		5:3:2	
		Root Colonization				Spore Number			
		%				Spore 10 g GM ⁻¹			
Control	I	7	±6 bc	0	±0 e	4	±2 d	4	±2 gh
	II	0	±0 c	3	±6 de	2	±1 d	2	±2 gh
	III	0	±0 c	3	±6 e	1	±1 d	4	±3 gh
	IV	0	±0 c	0	±0 e	1	±1 d	1	±1 h
	V	0	±0 c	10	±10 b-e	2	±1 d	1	±1 h
	VI	0	±0 c	7	±6 c-e	1	±1 d	2	±1 gh
	VII	7	±6 bc	0	±0 e	2	±1 d	3	±1 gh
	VIII	0	±0 c	0	±0 e	1	±0 d	4	±3 gh
		1.7 B		2.9 B		1.7 B		2.62 C	
<i>Fu. mosseae</i>	I	73	±15 a	27	±6 a-e	58	±10 bc	60	±26 b-f
	II	70	±17 a	33	±12 a-d	95	±7 ab	45	±19 d-h
	III	50	±10 ab	37	±6 a-c	69	±7 a-c	27	±6 f-h
	IV	50	±10 ab	43	±6 a	81	±18 a-c	55	±19 c-g
	V	57	±6 a	40	±20 ab	84	±13 a-c	62	±24 a-f
	VI	67	±31 a	40	±10 ab	64	±8 bc	68	±34 a-f
	VII	60	±20 a	40	±20 ab	62	±31 bc	65	±15 a-f
	VIII	63	±15 a	57	±15 a	75	±19 a-c	86	±23 a-e
		61.3 A		39.6 A		73.4 A		58.4 B	
<i>Cl. etunicatum</i>	I	37	±21 a-c	47	±6 a	83	±15 a-c	101	±23 a-c
	II	50	±0 ab	43	±6 a	48	±13 c	58	±19 c-f
	III	67	±15 a	33	±6 a-d	67	±13 bc	41	±18 e-h
	IV	50	±10 ab	50	±10 a	58	±12 bc	36	±3 e-h
	V	43	±12 a-c	50	±10 a	45	±16 c	46	±15 d-h
	VI	47	±6 ab	53	±15 a	54	±16 c	114	±27 a
	VII	60	±35 a	43	±15 a	81	±15 a-c	96	±21 a-d
	VIII	63	±6 a	50	±10 a	108	±16 a	112	±15 ab
		52.1 A		46.2 A		68.0 A		75.5 A	
Average		38.3 A		29.6 B		47.7 A		45.5 B	
Significancy	df								
Growing Media (G)	1	<0.001				0.375			
Mycorrhiza(M)	2	<0.001				<0.001			
Compost (C)	7	0.635				<0.001			
G X M	2	<0.001				<0.001			
M X C	14	0.870				<0.001			
G X C	7	0.340				<0.001			
G X M X C	14	0.054				0.020			

combinations. Previously Jan et al. (2014) found that application of compost and mycorrhiza significantly increased P uptake in the berseem plants.

The highest concentration of K (4.16%) in plants was determined under *Fu.mosseae*+compost number III prepared GM A. In the compost V added GM B has the highest K concentration (4.50%) in leek plants inoculated with *Fu. mosseae* (Table 5). The statistical differences between growing media determined that both P concentration and K concentration in plant tissues were higher in the GM B (5:3:2 growing media). In addition, mycorrhizal inoculation has an impact on the statistical significance of P % and K % concentrations in plant tissues ($P < .001$) (Table 5).

The highest plants Fe concentration in the GM A is observed under *Fu. mosseae*+ compost IV, the lowest Fe concentration was found under compost VII+*Fu. mosseae* application (Table 6). The highest Fe concentration 58.5 mg kg⁻¹ was observed under *Fu. mosseae* +compost V prepared GM B. Two different growing media, compost, and mycorrhizal applications have statistically significantly affected the Fe concentrations in plant tissues ($P < .001$) (Table 6).

It was determined that the Mn concentration in plant tissue varied between 25 mg kg⁻¹Mn (I compost) and 73.8 mg kg⁻¹Mn (VI compost) in the GM A. In the GM B, the highest Mn concentration – was determined under V-compost in the control plant without mycorrhiza . We

Table 5. Under two growth medias conditions the effect of different compost and mycorrhiza on P and K concentration of leek plant.

		1:1:1		5:3:2		1:1:1		5:3:2	
		P				K			
%									
Control	I	0.08	±0.0 g	0.10	±0.0 f	2.53	0.3 b	2.71	±0.3 b
	II	0.11	±0.0 fg	0.18	±0.0 d-f	2.91	0.7 ab	2.42	±0.1 b
	III	0.14	±0.0 e-g	0.19	±0.0 c-f	2.62	0.3 b	3.08	±0.1 b
	IV	0.20	±0.1 b-f	0.22	±0.0 b-f	2.67	0.1 b	2.70	±0.4 b
	V	0.16	±0.0 c-g	0.24	±0.0 a-e	2.95	0.5 ab	2.98	±0.2 b
	VI	0.15	±0.0 d-g	0.23	±0.1 a-e	3.04	0.3 ab	2.60	±0.0 b
	VII	0.10	±0.0 fg	0.14	±0.0 ef	2.92	0.6 ab	3.44	±0.5 ab
	VIII	0.12	±0.0 fg	0.14	±0.0 ef	3.49	0.7 ab	2.76	±0.3 b
		0.13 B		0.18 C		2.90 B		2.84 B	
<i>Fu. mosseae</i>	I	0.25	±0.0 a-e	0.34	±0.0 a	2.89	0.2 ab	3.25	±0.3 ab
	II	0.33	±0.0 a	0.33	±0.0 ab	2.85	0.6 ab	3.66	±0.7 ab
	III	0.26	±0.0 a-d	0.33	±0.0 ab	4.16	1.3 a	2.81	±0.3 b
	IV	0.27	±0.1 a-d	0.31	±0.0 a-c	3.50	0.7 ab	2.79	±0.2 b
	V	0.26	±0.0 a-d	0.29	±0.0 a-d	3.07	0.1 ab	4.50	±1.0 a
	VI	0.33	±0.0 a	0.27	±0.1 a-d	2.92	0.1 ab	3.22	±0.9 ab
	VII	0.29	±0.0 ab	0.34	±0.0 ab	2.78	0.3 ab	3.07	±0.1 b
	VIII	0.29	±0.0 ab	0.29	±0.0 a-d	2.66	0.3 b	3.27	±0.3 ab
		0.28 A		0.31 A		3.10 AB		3.32 A	
<i>Cl. etunicatum</i>	I	0.28	±0.0 ab	0.28	±0.0 a-d	3.67	0.5 ab	2.83	±0.2 b
	II	0.30	±0.0 ab	0.26	±0.0 a-e	2.94	0.1 ab	3.22	±0.1 ab
	III	0.29	±0.1 ab	0.27	±0.0 a-d	3.46	0.2 ab	4.55	±0.4 a
	IV	0.26	±0.0 a-d	0.27	±0.0 a-d	3.10	0.1 ab	3.67	±0.4 ab
	V	0.25	±0.0 a-d	0.25	±0.1 a-e	2.93	0.5 ab	3.00	±0.1 b
	VI	0.27	±0.0 a-c	0.27	±0.1 a-d	3.92	0.3 ab	3.23	±0.7 ab
	VII	0.31	±0.1 ab	0.28	±0.0 a-d	3.16	0.1 ab	2.80	±0.2 b
	VIII	0.27	±0.1 ab	0.27	±0.0 a-d	3.30	0.3 ab	3.60	±0.4 ab
		0.28 A		0.27 B		3.31 A		3.36 A	
Average		0.23 B		0.26 A		3.10 B		3.17 A	
Significancy	df								
Growing Media (G)	1	<0.001				0.351			
Mycorrhiza(M)	2	<0.001				<0.001			
Compost (C)	7	0.103				0.048			
G X M	2	<0.001				0.339			
M X C	14	<0.001				0.002			
G X C	7	0.640				0.309			
G X M X C	14	0.132				<0.001			

assume that the high concentration of Mn in the control plants does not relate to mycorrhiza application, while it may be caused by the high Mn concentration in the composts.

The Cu concentration in the tissues of the leek plant under *Fu. mosseae*+ VI compost+ 1:1:1 (v/v) growing media was determined as 19.1 mg kg⁻¹ Cu. In the 5:3:2 growth media, the highest copper concentration (14.1 mg kg⁻¹ Cu) was observed under *Fu. mosseae*+I compost application (Table 6).

It was determined that Zn concentrations in mycorrhizal plant tissues were higher than those not inoculated and was statistically significant ($P < .001$) (Table 6). The highest Zn concentration in plant tissues was obtained in the GM A + *Fu. mosseae* + compost VI, and in the GM B, the highest Zn tissue concentration was determined under *Cl. etunicatum*+VIII compost. Since the phosphorus and zinc are immobile in soil, it is assumed that augmentation of elements uptake mechanism is likewise given to the plant through mycorrhizal hyphae. It is broadly published, that Zn uptake is mostly controlled by phosphorus concentration, but some studies have shown that mycorrhizae increase Zn uptake as well as P uptake (Marschner 2012). In particular, in semi-arid climatic conditions, mycorrhiza has valuable contributions to the uptake of P and Zn (Ortas 2012; Raviv

2010). At the same time, the nutrient-rich organic materials added to the growing media have improved the leek plant nutrition.

The general averages between growing media were examined and determined that the microelements concentrations in the plant tissues in GM A were higher than in the GM B. However, GM B have higher shoot and root tissue P and K concentration than that in GM A. Results are shown that although compost-based growth medium have higher macro and micronutrients concentration for leek plant growth and nutrient uptake mycorrhizal inoculation is definitely needed for leek plant (Tables 5 and 6). Leek plant is significantly mycorrhizal dependent and under well-infected field and greenhouse conditions get high mineral nutrient especially P, Cu, and Zn (Ortas 2012). This is very important for the effects of mycorrhizal inoculation on plant nutrition acquisition under organic farming. Also the determination of statistical significance shows that mycorrhiza and growth media significantly affected microelement concentrations in plant tissues ($P < .001$) (Table 6).

Conclusion and recommendations

In general, obtained results are supporting our hypothesis. *Fu. mosseae* mycorrhiza inoculation has significantly increased leek plant growth, nutrient intake and spores' production, root colonization and relatively rich of nutrients growing media did not inhibit mycorrhizal development. *Cl. etunicatum* mycorrhizae inoculation significantly increased plant nutrient uptake and the number of spore. It has been determined that the GM A is more effective than the GM B, although both media have significantly positive impact on plant nutrition. Since GM B (Andesitic tuff: soil: compost (5:3:2 v/v)) have high organic matter than GM A, GM B used plant have high P and K nutrient concentrations. The highest nutrient concentration was observed in animal manure made IV compost (bovine manure) and V compost (ovine manure). Compost IV and V also have highest N and C concentration. GM A and GM B with mycorrhizal fungi inoculum were used in the cultivation of leek crops and it was determined to have the synergistic positive effect on plant growth and its nutrient concentrations. It can be concluded that the compost materials made from domestic wastes, bovine and ovine manure and compost collected from different plant materials are more suitable for plant production. Compost materials have been found to be rich in plant nutrients concentration, which have an effect on plant growth and nutrient uptake.

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