The Effect of Spent Mushroom Compost on the Growth, Mineral Nutrition and Heavy Metal Status of Lettuce (Lactuva sativa L.) and Spinach (Spinaceae oleraceae L.)

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***Abstract*— This research was carried out to determine the effects of spent mushroom compost (SMC) as an organic material source on the growth, plant nutrient and heavy metal content of lettuce and spinach plants grown in greenhouse soil. Lettuce and spinach plants were grown in pots containing different amounts of SMC (corresponding to 0, 20, 40, 60 and 80 T/ha, as dry weight basis). The effects of SMC on plant dry matter and N, P, K, Ca, Mg, Fe, Zn, Cu, Ni, Cd, Pb and Cr contents of lettuce and spinach plants were determined.**

SMC application increased soil organic matter and EC values but decreased pH value. No changes in soil mineral and heavy metal content were detected. SMC applications caused statistically important effects on dry matter yield, and N, P, K, Fe and Zn contents both in the lettuce and spinach plants. SMC applications increased yield until to 60 ton/ha of SMC application, but highest application rate of SMC compost depressed plant growth only in lettuce. Spinach plant was more tolerated to higher SMC levels than lettuce. All spent mushroom compost treatments resulted high mineral content both in lettuce and spinach.

No important changes in heavy metals except Fe and Zn were detected in all plants by SMC applications. All metal concentrations were ranged in background levels, below the phytotoxic maximum limits and no metals exceeded referenced food codex values by the SMC applications. This research showed that SMC could be applicable in vegetable cultivation at the agronomic rates without heavy metal contamination concern but salinity defects in salt sensitive plants should be taken into consideration.

***Keywords*— Spent Mushroom Compost, Mineral Nutrition, Heavy Metals, Lettuce, Spinach**.

I. Introduction

The use of Spent mushroom compost (SMC) is become to widespread in horticultural practices as a cheap and abundant waste organic material in mushroom cultivation industry areas alternative to manure. As in manure applications, SMC applications to soils result a number of beneficial effects. SMC contains valuable plant nutrients and organic matter that can improve soil fertility. It can supply plant nutrients to the crop and thus replace inorganic fertilizer. Trials have shown that it is an excellent source of phosphorus, potassium and trace elements but needs supplementation with nitrogen for best results. Plant nutrient value of the SMC is examined by most of the researchers and it is indicated that the nutrient combination is similar to soil arrangements, based on the organic wastes, applied to the agricultural areas routinely such as cattle manure and compost [1].

The phytonutritive capacity of compost has often been demonstrated to be analogous to that of manure; the same level of productivity, both quantitatively and qualitatively, can be maintained by replacing manure with compost [2]. However, SMC often contains high salt levels remaining from the fertilizer materials applied during mushroom cultivation. High or excessive soluble salts may be injurious to plants [3].

In this research, the effects of SMC applications to soil on soil chemical characteristics and soil metals and on plant nutrient contents and heavy metal accumulations in the lettuce and spinach plants those have different toleration to salinity were examined.

II. Material And Methods

A pot experiment was carried out in the greenhouse and lettuce and spinach plants those have different toleration to salinity [4] were grown in soil treated with SMC. SMC material was collected from mushroom cultivation plant in Korkuteli representative of the major mushroom growing area of Turkey. After collecting the fresh SMC, it was awaited in open air for 6 months, air dried, and applied to the soil.

In the experiment, plastic pots containing 10 kg soil were used. After 6 months open air treatment, SMC was applied to experimental soil as an oven-dry basis, corresponding at the following rates:

- SMC_0: no SMC application (control treatment)
- SMC_{20}: 20 ton/ha of SMC
- SMC_{40}: 40 ton/ha of SMC
- SMC_{60}: 60 ton/ha of SMC
- SMC_{80}: 80 ton/ha of SMC

Pots were arranged in a completely randomized design with four replicates in the greenhouse. Before beginning of experiment, all treatments received supplemental fertilization at a rate of 150, 50 and 100 mg kg^{-1} of N, P and K, respectively.

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Seedlings of lettuce were grown on peat-perlite mixture and were transplanted as two plants per pot. Spinach seeds were sowed to pot soil and after the germination, two spinach seedlings were stayed on the pot. All pots were located in the greenhouse under controlled climatic conditions. Pots were maintained around field capacity water tension by daily watering with distilled water. Sixty days after transplanting of lettuce and hand thinning of spinach, plants were harvested by cutting on the soil surface. Plant samples were washed by distilled water, dried at 65 ºC for 48 h and then ground. In dried leaf samples total N were determined by Kjeldahl method. Plant tissues were digested in aqua regia (1:3 HNO_3/HCl). In wet ashed leaf samples total P were determined by molibdophosphoric yellow colour method, total K, Ca, Mg, Fe, Zn, Mn, Cu, Cd, Ni abd Pb were determined by ICP-MS under optimized measurement conditions.

ANOVA procedures for a randomized complete block design and least significant differences (LSD) at P<0.05 of data were analyzed by SPSS-16 statistical program.

III. Results And Discussion

Soil and SMC chemical properties and heavy metal contents

Greenhouse soil and SMC general analytical characteristics are shown Table 1. The heavy metal contents of untreated greenhouse soil and SMC are well within the accepted normal range of values. A comparison of metal contents of SMC with that of untreated soil showed that the metal concentration Fe, Mn, Ni, Pb and Cr of SMC were not present in greater concentrations than in the soil. Zinc, Cu and Cd concentration of SMC was found greater. The heavy metal concentration of SMC is below the referenced levels indicated by the EU [5] for the agricultural use of waste organic material (sewage sludge).

At the end of experiment, changes in soil chemical parameters and heavy metal contents after treatment of SMC were presented in Table 2. Soil pH, EC and organic matter values were importantly changed by SMC applications. SMC applications increased EC value and organic matter content but decreased pH value of soil. All heavy metals were found in referenced heavy metal limits and no changes were detected in heavy metal contents in the soil by SMC applications. Increased EC values by SMC applications could be caused by high salt concentration of SMC. This shows us that salt content is an important factor for a sustainable SMC application and should be considered in horticultural cultivation before treatment.

Plant yield and heavy metal contents

The dry matter yield and the concentrations of N, P, K, Ca, Mg, Fe, Mn, Zn, Cu, Ni, Pb, Cd and Cr in the leaves of lettuce and spinach plants treated with SMC are presented in Table 3 and Table 4, respectively. The effect of spent mushroom compost on the dry matter yield of lettuce and spinach were found statistically important and SMC increased dry matter yield in both of plant. The best result for dry matter yield in both plants as regard to productivity was obtained at 60 ton/ha SMC applications. Dry matter yield decreased in lettuce plant at 80 ton/ha of SMC applications, possibly by high salinity. Whereas at 80 ton/ha of SMC applications, no changes in dry matter in spinach plant was observed. This may be possibly due to high toleration of spinach in saline conditions (Table 1 and Table 2).

TABLE I. THE ANALYTICAL CHARACTERISTIC OF THE EXPERIMENTAL SOIL AND SMC, AND THEIR POLLUTANT LIMITS.

Parameters	Soil	Limit values in soil[1] (pH<6- pH>6	SMC	Limit values in organic materials[1]
Texture	Loam		-	
pH- H2O (1:5 w/v)	7,62		6.74	
EC. (1:5 v/w) dS m^{-1}	0.205		7.85	
CaCO3, %	12,25		-	
Total N, %	0.21		2.35	
Organic Matter, %	2,76		68,21	
Fe, mg kg-1	12200	nls	387	nls
Mn, mg kg-1	460	nls	224	nls
Zn, mg kg-1	123	150-300	672	2500-4000
Cu, mg kg-1	32	50-140	55	1000-1750
Ni, mg kg-1	39	30-75	27	300-400
Pb, mg kg-1	27	50-300	6	750-1200
Cd, mg kg-1	0,55	1-3	0,62	20-40
Cr (total), mg kg-1	41	60-100	12	1000-1750

*: Below detection limit; (< 0.02 mg kg^{-1}); [1]: Total concentrations (mg kg^{-1} dry wt), [5]; nls: no limitation set

Plant N, P, K, Fe and Zn contents in both plant were found statistically important. N, P, K, Fe and Zn contents in both plant were increased by SMC applications, however no important changes in other nutrients and metal elements were detected (Table 3 and Table 4). Similar findings were reported in other SMC studies [6,7]. Mineral and heavy metals except P and K in Spinach plant were detected higher than lettuce plant. As can be seen in Table 2, nitrogen content of lettuce and spinach was below the background level. Nitrogen content was increased by SMC applications. This increase was attributed to increased N availability of SMC [8,9].

Although no changes were observed in soil Fe and Zn concentration by SMC applications, plant Fe and Zn contents increased by SMC treatments. This may be possibly caused by higher Zn content of SMC and the decreasing pH value caused by SMC application to soil. All metal concentrations were mostly ranged in background levels and below the phytotoxic maximum limits. SMC applications to soil did not resulted high metal accumulation in both plant and metals in both plant were not exceeded the referenced metal limits.

IV. Conclusion

The findings support that the SMC has positive effects on the growth of lettuce and spinach plants. It can be concluded from this perspective that SMC material can be usable without heavy metal contamination concern in horticultural practices. For this reason, the use of waste SMC may be an alternative safe organic material source in vegetable production, especially in organic farming practices. However, in the long-term SMC applications, high EC values of SMC and its risks on the soil salinity and plant growth should be considered.

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TABLE II. CHANGES IN SOIL CHEMICAL PARAMETERS AND HEAVY METAL CONTENTS AFTER TREATMENT WITH SMC.

Treatments	pH (1:5 w/v)	EC (1:5 v/w) dS m^{-1}	Organic matter %	Fe mg kg^{-1}	Mn mg kg^{-1}	Zn mg kg^{-1}	Cu mg kg^{-1}	Ni mg kg^{-1}	Pb mg kg^{-1}	Cd mg kg^{-1}	Cr mg kg^{-1}
SMC_0	7,62	0,37	2,76	12187	455	672	32	39	25	0,55	41
SMC_{20}	7,62	0,55	2,76	12186	462	680	32	35	28	0,55	39
SMC_{40}	7,59	2,33	2,82	12200	459	678	32	39	27	0,55	41
SMC_{60}	7,59	3,85	2,83	12179	445	688	34	42	28	0,55	44
SMC_{80}	7,60	4,74	2,85	12200	462	678	32	39	27	0,55	41
Significancy	*	**	*	ns	ns	ns	ns	ns	ns	ns	ns

**: $P<0.01$, *: $P<0.05$, ns: no significancy,; nls: no limitation set.

TABLE III. PLANT YIELD, NUTRIENTS AND HEAVY METAL CONTENTS IN DRY MATTER OF SPINACH PLANT TREATED WITH SMC.

Treatments	Dry matter g/pot	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	Ni	Pb	Cd	Cr
		%					mg kg-1							
SMC_0	33 c	3.24 d[1]	0,277 d	2.14 c	3,14	0,82	62 b	56	33b	7	1,1	3,0	0,25	0,04
SMC_{20}	44 b	3.67 c	0,315 c	2.31 b	3,21	0,88	66 b	62	34 b	7	0,8	2,7	0,25	0,06
SMC_{40}	57 a	4.14 b	0,335 b	2.43 b	2,99	0,78	71 b	77	44 b	9	1,2	2,9	0,30	0,07
SMC_{60}	67 a	4.67 a	0,344 a	2.51 a	3,18	0,85	78 a	79	58 a	8	1,1	3,1	0,25	0,05
SMC_{80}	61 a	4,66 a	0,355	2,58 a	3,14	0,92	82 a	78	62 a	9	1,2	3,2	0,30	0,07
Significancy	**	**	**	*	ns	ns	*	ns	*	ns	ns	ns	ns	ns
Background levels[2]		4-5	0,4-0,6	6-7	2,3-3,5	0,5-08	60-200	30-250	25-250	5-25	-	-	-	-
Phytotoxic levels[3]		-	-	-	-	-	-	-	100-400	20-100	10-100	30-300	5-30	5-30
Food codex lmits[4]							nls	nls	<20	<10	<10	<2	<0,05	<1,3

**: P<0.01, *: P<0.05, ns: no significancy, [1]: Means within an amendment followed by the same letter are not significantly different at the 005 level, [2]: [10] Jones et al (1991); [3]: [11] Kabata-Pendias (2000)[4]: Limitations for fresh vegetables [12].

TABLE IV. PLANT YIELD, NUTRIENTS AND HEAVY METAL CONTENTS IN DRY MATTER OF LETTUCE PLANT TREATED WITH SMC.

Treatments	Dry matter g/pot	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	Ni	Pb	Cd	Cr
		%					mg kg-1							
SMC_0	55 c	2,88 d[1]	0.425 d	3,22 c	2,74	0,49	79 b	67	24 b	5	0,8	3,1	0,30	0,05
SMC_{20}	62 b	2,96 c	0.459 c	3,53 b	2,81	0.51	75 b	71	23 b	5	0,8	3,2	0,35	0,07
SMC_{40}	73 a	3,15 b	0.538 b	3,45 b	2.88	0.59	88 a	79	27 b	5	0,9	2,8	0,35	0,05
SMC_{60}	68 a	3,25 a	0.564 a	3,88 a	3,15	0.62	90 a	77	32 a	7	0,8	3,3	0,30	0,06
SMC_{80}	57 b	3,32 a	0,574 a	3,77 a	2,78	0,58	98 a	81	35 a	7	0,9	3,0	0,35	0,07
Significancy	**	**	**	*	ns	ns	*	ns	*	ns	ns	ns	ns	ns
Background levels[2]		4-5	0,4-0,6	6-7	2,3-3,5	0,5-08	50-100	15-250	25-250	8-25	-	-	-	-
Phytotoxic levels[3]		-	-	-	-	-	nls	nls	100-400	20-100	10-100	30-300	5-30	5-30
Food codex lmits[4]							nls	nls	<20	<10	<10	<2	<0,05	<1,3

**: P<0.01, *: P<0.05, ns: no significancy, [1]: Means within an amendment followed by the same letter are not significantly different at the 005 level, [22]: [10] Jones et al (1991); [3]: [11] Kabata-Pendias (2000)[4]: Limitations for fresh vegetables [12].