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EFFECTS OF COMPOST APPLICATION ON NUTRIENT SUPPLY AND HEAVY METAL SORPTION OF SOIL

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Abstract: Analyzing the effects of compost application on chemical and microbiological soil properties, pot experiment was conducted with mixtures of a sandy-loam soil and compost originated from plant residues, including 0, 2.5, 5 and 10 v/v% compost, in four replicates. Ryegrass (*Lolium perenne* L.) was seeded in the pots, which were set up at 20°C in climate room by a daily irrigation to field capacity. The plants were cut at the 4th and the 7th week after seeding. Finally plant biomass and N, P and K content of plants was measured. Also chemical and microbiological properties of the soil-compost mixtures were determined. Same experiment was also carried out after 6 months incubation of soil-compost mixtures. During the incubation process the hot water soluble C and N content was determined monthly. The results reported an increase in growth and nutrient uptake of ryegrass plants at higher rate of compost application. Similar tendency could be detected between microbiological properties and compost application rate. These effects are more dominant when incubated soil-compost mixtures were used. Change of easily soluble C and N content during the incubation process was recognized by a decreasing tendency in case of C and an increasing in case of N. Furthermore the experiment was established to study Cu and Zn sorption capacity of the soil-compost mixtures. It was found that Cu and Zn fixation rose substantially as the quantity of compost increased. Increasing rates of compost reduced the availability of the heavy metals, however the availability of Cu was higher than that of Zn. Application of hot water extraction method showed that the soluble Cu and Zn increased by higher compost application rate.

Keywords: soil, compost, organic matter, microbial activity, copper, zinc

1. INTRODUCTION

Organic matter increase soil fertility in several ways and compost as an important source of organic matter has primary impacts on important soil properties. Based on the high nutrient mineralization potential and humus formation capacity, compost application can increase nutrient supply and organic matter content of soils. Organic matter plays also an important role in decreasing heavy metal availability.

The aim of the present study was to examine the effects of compost application on soil fertility and productivity, to investigate the effect of compost application on nutrient availability in soil, plant biomass production and nutrient uptake of plants. To show the change of organic matter content during the incubation of soil-compost mixtures, C and N contents were determined. Furthermore also important microbial parameters were analyzed. Finally the effect of compost application on Cu and Zn sorption in soil and plant availability was examined.

2. MATERIALS AND METHODS

2.1. Pot experiment analyzing nutrient supply and microbial activity

Compost was applied to the soil in 0, 2.5, 5 and 10 v/v %. Soil (classified as Luvisol) was sampled from the top layer (0-20 cm) of agricultural land in Gödöllő, Hungary and compost originated from plant residues. Analysis of pH (KCl), $CaCO_3$-content, humus-content was carried out according to Buzás (1988), AL (ammonium-lactate) soluble P and K content according to Egner et al., (1960). Furthermore HWP (hot water percolation) soluble C, N, P and K content were determined as described by Füleky and Czinkota (1993). Table 1 gives an overview about important chemical properties of soil-compost mixtures at different rates of compost application.

One half of the soil-compost mixtures were set up at standard 20°C in climate room for 6 months incubation. During the incubation process the HWP soluble C and N content was determined monthly using the method of Füleky and Czinkota (1993). Using these soil-compost mixtures of both the incubated and non-incubated, pot experiments were conducted with four replicates in complete randomized block design. Each pot contained 1000 g soil and was seeded with ap. 2 g of ryegrass (*Lolium perenne* L.). Pots were set up at standard 20°C in climate room by a daily irrigation field capacity. The plants were cut two times: after the 4^{th} and the 7^{th} week. Plants biomass was measured and N, P and K content was analyzed regarding to Sarkadi and Krámer (1960).

After harvesting the plants also microbiological properties of soil-compost mixtures were determined: Determinations of total organic C, water soluble C and hot water soluble C were carried out by the methods of Walkley and Black (1934), Sims and Haby (1971), Haynes et al., (1991), respectively. Microbial biomass carbon (MBC) was determined by chloroform fumigation extraction method (Gregorich, 1990). Soil respiration was determined (Alef, 1995a) by trapping the evolved CO_2 in NaOH and back titrated with HCl. Enzymatic activities were determined for following: Fluorescein diacetate activity by measuring the released fluorescein at 490 nm by the method described by Alef (1995b). Dehydrogenase activity was measured by the method of García et al. (1993). Urease activity was determined according to the method of Nannipieri et al., (1980). Aryl-sulphatase activity as proposed by Tabatabai and Bremmer (1970), after the incubation of soil with p-nitrophenyl sulphate and measured at 400 nm. Phosphatase activity was measured according to Tabatabai and Bremmer (1969) and β-glucosidase activity according to Masciandaro (1994). Furthermore, the total mesophilic aerobic heterotrophic bacterial and fungal populations were counted according to Szegi (1979). Cellulose decomposers were detected according to Hendricks et al. (1995) and phosphate solubilizers were determined according to Goldstein (1986).

2.2. Biotest analyzing heavy metal sorption capacity

The following part of the experiment was conducted with the purpose to analyze the heavy metal sorption capacity of soil-compost mixtures using a rapid biotest method. The method was developed by Standford and Dement (1957) and modified by Nooman and Füleky (1989). Soil-compost mixtures were prepared in the way as described above. The Cu and Zn treated soil-compost mixture samples were incubated in climate room at standard 20°C for 30 days. Cu was added in form of $CuSO_4$ solution in a concentration of 75 mg kg^{-1} and 150 mg kg^{-1}, respectively, while Zn in form of $ZnSO_4$ solution in a concentration of 200 mg kg^{-1}, 400 mg kg^{-1}, respectively. Ryegrass seeds of 1 g were germinated on the surface of wetted cotton for 10 days. After 10 days the plants were set in pots including 200 g soil and compost mixture, where they have begun a rapid nutrient uptake. The plants were irrigated daily to field capacity and were cut 10 days after putting them on the soil-compost mixtures. Cu and Zn content were measured on atomic adsorption spectrophotometer after HCl hydrolysis (Buzás, 1988). Desorption capacity was measured by the Hot Water Percolation (HWP) method (Füleky and Czinkota, 1993). 30g soil was extracted with hot water and from the extract Cu and Zn contents were determined as described by Buzás (1988). Furthermore adsorption capacity of soil-compost mixtures were determined by the addition of Cu as $CuSO_4$ solution in 0, 50, 100, 250, 500, 750, 1000, 1500, 2000, 2500, 3000, 4000 and 5000mgkg^{-1} concentrations and Zn as $ZnSO_4$ solution in 0, 50, 100, 250, 500, 750, 1000, 2500, 5000 and 10000 mg kg^{-1} concentrations. 10 ml solution was added to 1 g soil, the established suspension was shaken 24 hours long and finally centrifuged for 5 minutes to depart the solution.

Table 1. Important chemical properties of the soil and compost mixtures

	0% (soil)	2,5%	5%	10%	compost
pH (KCl)	6,40	6,33	6,55	6,55	7,33
$CaCO_3$ %	0	0	0	0	1,20
humus content %	1,04	1,42	1,62	1,98	10,31
N_{total} %	0,09	0,10	0,18	1,10	1,10
AL-P mg kg^{-1}	43,01	51,12	118,50	141,63	130,01
AL-K mg kg^{-1}	114,13	197,79	267,13	346,81	2796,27

From this solution Cu and Zn content was measured. On the adsorption data a Langmuir function was fitted, according to which maximally bound amount of Cu and Zn were determined.

All data were expressed on the basis of oven-dry weight of soil and plant samples. The results reported are the means of determinations made on four replicates. Analysis of variance was performed in MS Excel and means were reported with a least significant difference at the 5% level.

3. RESULTS AND DISCUSSION

3.1. Biomass production and N, P and K content of plants

Results reported in table 2.a. stated the plant biomass production has increased significantly in case of soil treated with 5% and 10% compost in comparison with the control treatment. Plant biomass production was more positively significant if incubated soil-compost mixture was applied. The highest plant biomass was detected at 10% compost application with incubation. The N, P and K content of the ryegrass plants are presented in tables 2.b., c., d., respectively. The results indicate a significantly increase of N, P and K in the plant tissue at 10% compost application. In case of N also 5% compost application and in case of P also 2,5% compost application caused a significantly higher nutrient content in the plant tissues. The results show that incubation also increased N, P and K content of plants. This increase was significantly higher by increasing the mixture rate of compost in the soil samples. Similar results are reported by Yavari et al., (2009) in case of N and K, however at low P supply by organic matter application.

3.2. C, N, P and K content of soil

Soil samples treated with higher compost ratios show higher C and N contents as well as P and K contents. These increases in measurements of C, N, P and K were due to the increases in compost application rates (Tables 3 a, b, c, and d, respectively).

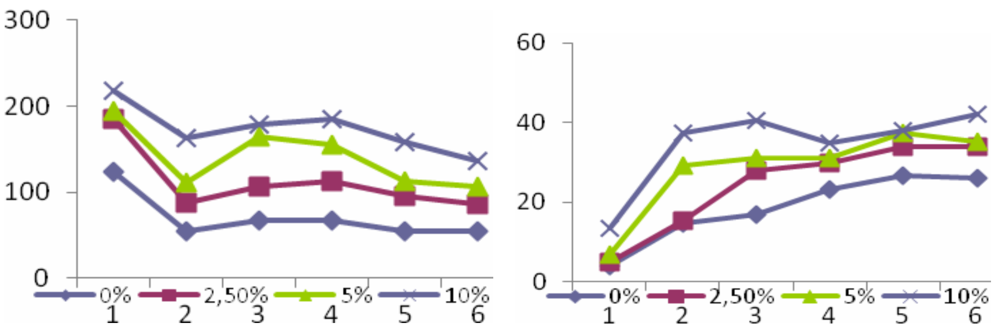
The loss of HWP soluble C content during the incubation is shown on figure 1. After the first month of incubation a rapid decrease of carbon is to detect. This is followed by a slightly growth and decreases again after the 4th month. Effect of the 6 months incubation is in case of all treatments a decrease of HWP soluble C content. The N content (Fig. 2.) increased continuously during the incubation. Treatments containing higher compost ratio incubated resulted in significantly higher HWP soluble N contents. Regarding to change of C and C content during incubation, similar results are reported by Vuorinen and Saharinen (1997). Contrary to this, Said-Pullicino et al., (2006) reported an increase of water-soluble carbon during this process.

Table 2. Dry matter amount, N, P and K content of ryegrass plants

a) Plant biomass (g pot^{-1})						
Treatment	0%	2,5%	5%	10%	Average	SD(5%)
No incubation	0,83	1,62	1,89	2,13	**1,61**	**0,90**
Incubation	1,8	3,07	3,82	8,03	**4,19**	
Average	**1,33**	**2,35**	**2,86**	**5,08**	**2,90**	
SD (5%)	**1,28**					
b) N (mg pot^{-1})						
Treatment	0%	2,5%	5%	10%	Average	SD(5%)
No incubation	2,90	5,20	5,95	7,60	**5,41**	**3,99**
Incubation	7,00	12,01	21,80	40,50	**20,33**	
Average	**4,95**	**8,60**	**13,88**	**24,05**	**12,87**	
SD (5%)	**5,64**					
c) P (mg pot^{-1})						
Treatment	0%	2,5%	5%	10%	Average	SD(5%)
No incubation	0,026	0,038	0,052	0,061	**0,044**	**1,21**
Incubation	0,57	5,80	1,825	4,175	**3,09**	
Average	**0,30**	**2,92**	**0,94**	**2,12**	**1,57**	
SD (5%)	**1,71**					
d) K (mg pot^{-1})						
Treatment	0%	2,5%	5%	10%	Average	SD(5%)
No incubation	0,69	2,20	3,65	6,35	**3,22**	**3,85**
Incubation	2,20	5,20	6,80	24,50	**9,68**	
Average	**1,45**	**3,70**	**5,23**	**15,43**	**6,45**	
SD (5%)	**5,45**					

Table 3. HWP soluble C, N, P and K content of soil-compost mixtures

a) HWP-C (mg kg^{-1})						
Treatment	0	2,5	5	10	Average	SD(5%)
No incubation	123,25	185,25	193,25	218,00	**179,95**	**159,31**
Incubation	54,25	85,25	105,25	441,25	**171,50**	
Average	**88,75**	**135,25**	**149,25**	**329,63**	**175,72**	
SD (5%)	**225,30**					
b) HWP-N (mg kg^{-1})						
Treatment	0	2,5	5	10	Average	SD(5%)
No incubation	3,83	5,75	6,25	12,75	**7,14**	**0,64**
Incubation	26,00	33,80	35,10	42,00	**34,23**	
Average	**14,91**	**19,78**	**20,68**	**27,38**	**20,68**	
SD (5%)	**0,90**					
c) HWP-P (mg kg^{-1})						
Treatment	0	2,5	5	10	Average	SD(5%)
No incubation	0,46	0,54	1,06	1,01	**0,77**	**0,17**
Incubation	1,70	1,69	2,49	3,52	**2,35**	
Average	**1,08**	**1,12**	**1,77**	**2,27**	**1,56**	
SD (5%)	**0,24**					
d) HWP-K (mg kg^{-1})						
Treatment	0	2,5	5	10	Average	SD(5%)
No incubation	12,37	25,86	39,05	57,37	**33,66**	**0,92**
Incubation	12,50	26,50	41,50	57,50	**34,50**	
Average	**12,44**	**26,18**	**40,28**	**57,44**	**34,08**	
SD (5%)	**0,88**					



1.A. HWP-C content (mg/kg) 1.B. HWP-N content (mg/kg)

Figure 1. Changing of HWP-C (1.A.) and HWP-N (1.B.) content during the incubation. x axys: months; y axys: C/ N content.

Huang and Chen (2009) also describe an increasing tendency of nitrogen during incubation, which might be explained with the mineralization of organic nitrogen sources during the incubation.

3.3. Detection of soil microbial activity

Changes in soil microbial activity, biomass, community structure, enzyme activities, and soil quality resulting from compost amendments were determined in soil samples with different treatments to understand the effects of organic matter application practices on soil microbial properties of the investigated soil samples. The soil samples were varied in microbial and enzymatic activities. The community structures of eubacteria and fungi were examined using classical and modern techniques suggested the direct relationships existed between microbial community structure, enzyme activities and the rate of compost application.

Microbial biomass and activity changed as a result of compost amendment and microbial community structure was more strongly influenced by incubation time intervals. The addition of 10% of compost was sufficient to stimulate the microbial community in soil samples, resulting in microbial biomass growth and increased enzymatic activities and indirectly the soil quality.

These increases in the numbers of microbial population densities in the short term application of compost suggests that the nutritive values present in these cultivated mixtures especially P and N were potentially contained in high amount. Impact of compost-heavy metals on the soil microbial populations was studied. Unicellular yeasts were the most probable fungi in all concentrations, but its population increased by increasing the compost dose. The most fungal isolates were belonging to the genera of *Alternaria*, *Aspergillus*, *Cephalosporium*, *Cladosporium*, *Fusarium*, *Geotricum*, *Mucor*, *Penicillium*, *Rhizopus* and *Trichoderma*. Also, many isolates of the genus *Saccharomyces* were isolated from soil samples of the rhizospheres of the tested plants amended with compost comparing with the control soil. The most frequently bacterial isolates were belonging to *Acinetobacter*, *Azotobacter*, *Brevundimonas*, *Cellulomonas*, *Chromobacterium*, *Corynebacterium*, *Enterobacter, Escherichia*, *Flavobacterium*, *Klebsiella*, *Micrococcus*, *Proteus*, *Streptococcus*, *Serratia* and *Zooglea*. *Streptomyces* was the genus of most dominant isolates of actinomycetes. Percentage of Gram negative and Gram positive rhizobacteria was determined and it was found that the ratios between the counted Gram negative to Gram positive rhizobacteria in the rhizospheres of rye grass grown in soil and soil-compost mixture were 8/5 and 9/7, respectively. While the ratios of rods shape bacteria to cocci forms were 5/2 and 6/2, respectively. It was found that fluorescent pseudomonads occupied 21.8% of the total rod shape Gram negative bacteria while the spore-forming bacteria of *Bacillus* sp. that was the most common Gram positive bacteria isolated from all soil treated with compost occupied 89.4%. Commonly, it was found that the ratio between Gram negative and Gram positive bacteria in the studied rhizospheres was mainly 3.73. The biochemical characteristics of soil samples mixed with different rates or compost are shown in tables 4, 5, 6. and 7. The analyzed microbial features reached their maximal after incubation in the growing period.

Results showed that compared to the control and application of compost illustrated no highly significant effect on SOC and C_{microb}. This showed that application of compost is an effective way of enhancing SOM and microbial biomass as well as the dehydrogenase, urease, β-glucosidase and aryl-sulphatase activities and plant productivity in the form of RPDW in clay loam brown forest soil. Organic amendment to soil is rapidly decomposed by microbial transformation, releasing essential nutrients such as N and P. Stimulation of microbial biomass and enzyme activities in soil is usually greater in organically than in inorganically fertilized soils. Jiménez et al., (2007) evaluated the effects of compost (CDS) on β-glucosidase activity, total (TCH) and extractable (ECH) carbohydrate content, MBC and Basal Respiration (BR) of soils under laboratory conditions. The results showed that the addition of organic matter increased all the studied soil parameters, and the increase depended on the amount of compost. These results supported our results, but we are not agree with the authors in the case of TCH and ECH, the enhancing effect decreased with time, in which our results were dependent on time. Finally, we were agreed at the end of incubation, parameters of the treated soils were higher than those of the control. BR, MBC and β-glucosidase activity were the best measured parameters in distinguishing the long-term effects.

Table 4. Effect of incubation time on basal respiration and microbial biomass carbon in soil amended with compost

	Treatments				SD(5%)
	0%	2,5%	5%	10%	
Basal Respiration (CO_2-release)					
No incubation	1.5	3.0775	4.5225	6,235	1,87
Incubation	1.6275	3.905	4.9675	8.2075	2,53
Microbial Biomass Carbon (MBC)					
No incubation	252	291.125	312.875	358.1	40,97
Incubation	277.2	315.65	353.5	381.2	41,93

Table 5. Effect of incubation time on total organic C, water soluble C and hot water soluble C in soil amended with compost

	Treatments				SD(5%)
	0%	2,5%	5%	10%	
Total Organic Carbon (TOC)					
No incubation	0.6685	1.1065	2.03525	3.50425	1,16
Incubation	0.686	1.66225	2.713	4.797	1,63
Water Soluble Carbon (WSC)					
No incubation	101	228.25	340.75	456.5	140,97
Incubation	108.25	321.25	427.25	582	184,15
Hot Water Soluble Carbon (HWSC)					
No incubation	108.25	196.75	299.25	409.75	120,51
Incubation	122.75	241.5	421	530.75	168,49

Table 6. Effect of incubation time on enzymatic activities in soil amended with compost

	Treatments				SD(5%)
	0%	2,5%	5%	10%	
Fluorescein diacetate activity (FDA)					
No incubation	35.25	55.75	74.25	98	24,74
Incubation	44	75.5	97.5	132.25	34,39
Dehydrogenase activity (DA)					
No incubation	55.275	74.35	95.1	143.825	35,28
Incubation	83.3	112.2	153.85	211.875	51,67
Urease activity (UA)					
No incubation	1,1025	1.6	2.0475	2.8575	0,69
Incubation	1.4725	1.82	2.3975	3.4125	0,79
Aryl-sulphatase activity (ASA)					
No incubation	30.85	55.4	77.575	100.75	27,20
Incubation	37.275	76.825	113.1	134.35	39,47
Phosphatase activity (PhA)					
No incubation	55.8	74.6	96.25	132.45	30,46
Incubation	79.15	88.25	127.225	160.025	35,39
β-glucosidase activity (GA)					
No incubation	39.96	62.7	80.875	104.25	25,26
Incubation	53.875	77.45	116.925	173.2	48,30

Table 7. Effect of incubation time on some microbial population density in soil amended with compost

	Treatments				SD(5%)
	0%	2,5%	5%	10%	
Bacterial population (10^5)					
No incubation	0.67	44.4	77.3	132.375	51,40
Incubation	1.38	61.95	113.225	167.95	65,89
Fungal population (10^4)					
No incubation	1.5825	3.755	6.5	12.85	4,52
Incubation	2.365	5.4625	8.645	16.895	5,79
Cellulose-decomposers (10^3)					
No incubation	3.5	6.4	8.15	11.25	3,11
Incubation	3.94	8.91	15.055	18.175	5,87
Phosphate solubilizing microorganisms (10^2)					
No incubation	1.725	3.425	8.25	11.2	4,28
Incubation	2.415	4.7925	10.2325	15.4675	5,40

Our results are confirmed also by the results of Moreno et al., (1999) who found that compost increased the total organic C, humic substance and water-soluble C contents, the beneficial effects still being noticeable after 120 days of incubation.

3.4. Cu and Zn sorption of soil

Even the higher amount of Cu treatment (150 mg kg^{-1}) did not result in any toxic effect on plant growth. Higher amount in compost caused an increase in plant biomass production, although the effects is not statistical significant. Increasing the Zn treatment from 200 to 400 mg kg^{-1} has increased the plant biomass production in case of the treatment without compost. Treatments, where compost was added to soil, did not show this toxic effect. Cu uptake (Table 8) of plants did not change by increasing amount of added Cu. However, by higher amount of compost Cu uptake of plants has decreased. Opposite tendency was detected by the Zn treatments (Table 8): higher amount of Zn application has also increased the plant uptake. Similar as by Cu, higher amount of compost has caused a decrease of plant uptake.

After the plants have been cut, from the soil also HWP soluble Cu and Zn contents were determined (Table 9). Cu content has increased only slightly in case of higher treatments, however Zn content has increased much higher, but not any more by the addition of 10% compost. Higher compost amount has resulted both in the case of Cu and Zn in an increase of the HWP soluble element content. This tendency might be explain by the heavy metal mobilization effect of organic matter. Langmuir isotherm is frequently used for determination of adsorption parameters.

Table 8. Cu and Zn uptake of ryegrass (mg pot^{-1})

Cu/Zn treatments	Treatments				Average	SD(5%)
	0%	2,5%	5%	10%		
Cu						
75	0,0024	0,0022	0,0019	0,0019	0,0021	0,0008
150	0,0028	0,0020	0,0018	0,0016	0,0021	
Average	0,0026	0,0021	0,0019	0,0017	0,0021	
SD(5%)	0,0005					
Zn						
200	0,12	0,047	0,038	0,034	0,060	0,02
400	0,26	0,067	0,052	0,032	0,10	
Average	0,19	0,057	0,045	0,033	0,082	
SD(5%)	0,02					

Table 9. HWP soluble Cu and Zn content of soil-compost mixtures (mg kg^{-1})

Cu/Zn treatments	Treatments				Average	SD(5%)
	0	2,5	5	10		
Cu (mg kg^{-1})						
75	0,6	0,8	1,4	1,6	1,1	0,7
150	0,6	1,3	1,7	2,5	1,5	
Average	0,6	1,0	1,5	2,1	1,3	
SD(5%)	0,5					
Zn (mg kg^{-1})						
200	1,8	4,0	7,8	19,9	8,4	3,7
400	6,3	9,7	13,7	22,9	13,1	
Average	4,0	6,9	10,7	21,4	1,8	
SD(5%)	2,6					

Table 10. Maximum Cu and Zn sorption of soil-compost mixtures

Treatment	Cu	Zn
	max. sorption capacity mg kg^{-1}	max. sorption capacity mg kg^{-1}
0%	1896,9	2441,3
2,5%	2092,6	2782,2
5%	2777,7	2919,4
10%	3854,7	3054,4

The isotherm measures the relation between the equilibrium concentration of the adsorbate in the solid phase and the equilibrium concentration in the aqueous phase. This relation show an increasing sorption capacity by increasing compost application rate. The addition of 10% compost compared to the treatment without compost has caused the double amount of maximal Cu sorption, but only a 20% increase of the maximal Zn sorption (Table 10). This tendency shows strong relations to plant uptake of these elements. In case of Zn, increase of compost amount is a less effective solution, furthermore both the water solubility and plant availability is much higher. Regarding to these results, Farrel and Jones (2010) Li et al., (2010) and Tapia et al., (2010) reports that Cu and Zn were bound by soil organic matter.

4. CONCLUSIONS

The results illustrate that the increasing tendency of the N, P and K content in soil was similar to those in the plant tissues and due to the increasing mixing rate of compost. Results also indicate that the incubation increases the available nitrogen content in soil. However incubation decreases the C content which increases with higher rate of compost amendments. Also a positive relation between increasing compost application rate to soil and microbial activity could be recognized. Analyzing heavy metal sorption capacity it was found that Cu and Zn fixation rose substantially as the quantity of compost increased. Increasing rates of compost reduced the availability of the heavy metals, however the availability of Cu was higher than that of Zn. Application of hot water extraction method showed that the soluble Cu and Zn increased by higher compost application rate.

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