Effect of pruning waste compost on elemental content of soil, alfalfa (*Medicago sativa* L.) and Rhodes grass (*Chloris gayana* L.)

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ABSTRACT

The objective of this research was to determine the uptake of heavy metals by plants grown on compost-treated soil. The study took place at El-Bostan region at Nubaria. Soil and two crops; alfalfa and Rhodes grass, were sampled in 2004 after applying a total of 32 t/ha/year to the soil. The control received only inorganic fertilizers. Four heavy metals were analyzed (Cd, Cr, Ni, Pb), as well as nine essential elements (N, P, K, Ca, Mg. Cu, Fe, Mn, Zn).

Compost treated soil in compost lysimeters had more N, P, K, Mg, Fe, Cu, Mn, Zn, Cd, Cr and Ni than did soil from the control lysimeters. In general, concentrations of essential elements in plants grown on compost treated soils were similar to the concentrations of essential elements in plants grown with inorganic fertilizer. Concentrations of heavy metals were also similar, except for Cd in stems of alfalfa; Cr in roots of Rhodes grass; Ni in roots and seeds of Rhodes grass and Pb in roots of Rhodes grass. Nickel in seeds of Rhodes grass grown with compost was within the normal concentration range. Cadmium was at low levels in all plants, which indicated that, when compost was applied to the soil; its transfer from the soil to the plants was low. Additional of pruning waste compost appeared to be an effective method for fertilizing plants

INTRODUCTION

In search of a better destination for residues produced by both domestic and industrial activities, composting stands as a feasible alternative. This technique emphasizes recycling, contributes meaningfully to the reduction of the original volume, does not degrade the environment and eliminates pathogens (Escosteguy et al., 1993; Pereira Neto, 1994; Scarlato and Pontin, 1995).

According to Costa (1986), the effect of compost from organic residues goes beyond biological mechanisms of the soil. Researches conducted by Lima et al., (1997 a, b, c) proved the beneficial action of compost on the physical-chemical properties of the soil and on the plant development.

Numerous studies have demonstrated that these organic residues, after proper composting, can be used with very good results as fertilizers (Scarlato and Pontin, 1995).

Biowaste compost from trimming of plants and lawns (green waste compost) is a valuable organic fertilizer and soil conditioner, which supply nutrients as well as humus (Vogtmann et al., 1993). Management of biowaste compost for beneficial use in agriculture must take into account strategies to meet crop nutrient needs and protect the environment. On average, biowaste compost contains 11.5g/kg total N (Vogtmann et al., 1993), yet the N is present mostly in the organic form and therefore is not readily available to plants. This N can be mineralized and be taken up by the plant, immobilized, denitrified and/or leached.

There is concern that crops grown on soils with biowaste compost may accumulate non-essential, heavy elements in amount toxic to man and animals eating the crop. Many studies have evaluated the availability of heavy elements in biowaste spread on the surface of the soil (Baker and Brooke, 1989, Baker et al., 1994, Entry et al., 1996, McGrath et al., 1997, Burken and Schnoor, 1998, Robinson et al., 2000 and Stoltz and Geger, 2002).

Apparently, little information has been published on the concentration of heavy elements in soils treated with compost in Egypt. The purpose of this experiment was to determine the availability, to alfalfa (*Medicago sativa* L.) and Rhodes grass (*Chloris gayana L.*) of non-essential elements (Cd, Cr, Ni, Pb) in the soil to which pruning waste compost was applied. Concentrations of elements known to be essential for plant growth (N, P, K, Ca, Mg, Cu, Fe, Mn, Zn) were also analyzed.

MATERIALS AND METHODS

The experiment was conducted in lysimeters at El-Bostan, Nubaria region. Using soil treated with compost randomly equated and mixed with the soil in an equivalent dose of 60 t/ha and for comparison

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inorganically fertilized control. The compost was uniformly mixed with air-dried soil sieved at < 2 mm and placed in the lysimeters.

The compost used (leaves and grass clippings) in the present study was obtained from pruning waste. Although there are some seasonal variations in the quantities and characteristics of green waste in El-Bostan, approximately 60 – 70% of the waste volume manufactured is woody material, mainly from date palm and the rest from leaves to grass clippings. The green waste was composted in the composting facility of Nubaria Research Station.

Window piles 2.5 m high by 10 m long were constructed using shredded material. Forced aeration was used for the first eight weeks (bio-oxidative phase), followed by a ten-month maturation period during which the piles were turned periodically to maintain adequate O_2 levels. During the bio-oxidative phase of composting air was blown through the holes of two tubes placed at the base of the pile. The ceiling temperature for continuous aeration was 70°C. The O_2 saturation level was also controlled and when it fell below 82%, the aeration system was turned on. During the maturation phase the pile was turned every 15 days in order to improve both O_2 level inside the pile and the homogeneity of the material. Pile moisture was controlled weekly by adding water to obtain a moisture content not less than 50%. The end product was passed through 10 mm sieve. Table 1 shows the chemical characteristics of randomly collected pruning waste compost.

The two crops used in this experiment are alfalfa (*Medicago sativa* L.) and Rhodes grass (*Chloris gayana* L.). The compost and control lysimeters have been treated in the same way except that only inorganic fertilizer has been used on the control lysimeters. The following amounts of inorganic fertilizer 130 kg/ha N as urea, 75 and 60 kg /ha P as tripelphosphate and K as potassium sulfate, respectively were added. Three replicates were used for each treatment.

Composite soil samples from each lysimeter were randomly collected from each treatment. Soil were analyzed for: pH (soil/water ratio, 1 : 1) (Peech, 1965); extractable P (Olsen et al., 1954); exchangeable K, Ca and Mg (Chapman, 1965); DTPA-extractable Cu, Fe, Mn and Zn (Lindsay and Norvell, 1978); Cd, Cr, Ni and Pb were determined using atomic absorption spectroscopy (Isaac and Kerber, 1971). NH_4-N and NO_3-N (Bremner. 1965) and soluble salts (electrical conductivity) of a saturation extract (Bower and Wilcox, 1965).

Alfalfa and Rhodes grass were planted in 15 Feb. 2004 and sampled in 15 August 2004, when the leaves were still green. Roots, leaves and stems were analyzed for N, P, K, Ca, Mg, Cu, Fe, Mn, Zn, Cd, Cr, Ni and Pb.

Data reported in the text are the means of determination made on three replicates and reported on a dry-weight basis (oven dried at 105°C for 24 hr). Duncan's new multiple range test (5% level) was used to determine significant differences between the two treatments (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Soil characteristics

The soil texture is loamy sand and the level of salinity is 2.28 dS/m (Table 1). According to that of the United States Salinity Laboratory Staff (1954), the soil is suitable for normal plant growth. The pH value of the soil is 7.4. This is within the optimum range reported by Zucconi and Berttoldi (1987) for optimum plant nutrition, (between 6.50 and 8.50). The organic matter of this soil was low (1.72%). The results also showed the low cations exchange capacity of the soil (14.6 comlc/kg). The soil is also characterized by low levels of N and high levels of P, K, Ca and Mg. The mean concentrations of Cu, Pb, Zn, Fe and Mn were 4.7, 9.4, 59.5, 341.7 and 27.2 mg/kg respectively.

Compost characteristics

The characteristics of the prepared compost are shown in Table 1. EC in a water extract did not exceed

Table 1. Chemical properties of the used soil and compost on dry weight basis.

Parameters	Soil	Compost
EC (dS/m)	2.28	2.47
pH	7.4	8.2
OM (%)	1.72	88.3
CEC ($coml_c$/kg)	14.6	132
NO_3^- (mg/kg)	17.9	30.2
P-$NaHCO_3$ (mg/kg)	27.3	41.7
K-NH_4OAC (mg/kg)	155.6	164.3
Ca- NH_4OAC (mg/kg)	8322.5	2480.7
Mg-NH_4OAC (mg/kg)	3175.0	5496.0
Cu-DTPA (mg/kg)	4.7	4.1
Pb-DTPA (mg/kg)	9.4	11.4
Zn-DTPA (mg/kg)	59.5	53.6
Fe-DTPA (mg/kg)	347.1	238.9
Mn-DTPA (mg/kg)	27.2	25.9

the limit value of 3 dS/m recommended by V. L.A.C.O. (1995). pH value was slightly alkaline (8.2) and was within the normal range for plant growth (Zucconi and Berttoldi, 1987). Organic matter and total nitrogen content (30.2 mg/kg) were above the minimum level required by V.L.A.C.O. (1995).

Total heavy metals (Table 1) were below the limit values set by the European Communities for biosolids intended for agricultural use (Council of European Communities, 1986). This implies that this material can be used in agriculture.

The lysimeter experiment

Table 2 showed that the pH of the treated soil with compost was less than that of the soil treated with inorganic fertilizer. Difference in the pH values of the compost and inorganic fertilizer probably contributed to their different effect on soil pH. Compost can lower the pH of soils because of the nitrification reaction and the microbial production of CO_2 (Pocknee and Summer, 1997). Concentrations of soluble salts were higher in the compost treated soil than in the conventionally fertilized soil. At 0-2 dS/m, salinity effects are mostly negligible and at 2-4 dS/m, yields of very sensitive crops may be restricted (Bernstein, 1964). The crops grown in the lysimeters (alfalfa and Rhodas grass) have medium salt tolerance (United States Salinity Laboratory Staff, 1954) and no salt damage was observed.

The NH_4-N concentration in the soil with compost was greater than that in the soil with inorganic fertilizer. But the differences were not significant. Compost significantly increased the NO_3-N and P concentrations, the N and P fertilizing value of compost is well known (Ouedraogo et al., 2001 and Pinamonti et al., 1997) the high NO_3-N content of the soil with compost indicated that the N in the compost was being mineralized to NO_3-N. Potassium concentrations were also increased by compost application. Soil with compost and soil with inorganic fertilizer had similar effect on the concentrations of Ca. The concentration of Mg in soil with compost was greater than that in soil with inorganic fertilizer. Concentrations of essential trace elements in the soil (Cu, Fe, Mn, Zn) were usually increased by compost, especially Fe, Mn and Zn.

Table 3 shows the concentrations of Cd, Cr, Ni and Pb in both soils. Compost increased concentrations of Cd of the soil. The concentration of Cr was not elevated significantly by compost, concentration of Ni was significantly higher in soil with compost than in soil with inorganic fertilizer. fertilizer and compost treated soil had similar concentrations of Pb.

Table 2. pH, and elemental composition of loamy sand soil treated with compost and inorganic fertilizer.

Parameters	Compost	inorganic
pH	7.2b	7.7a
NH_4-N (mg/kg)	7.3a	6.9a
NO_3-N (mg/kg)	38.8a	12.3b
P-$NaHCO_3$ (μg/g)	68a	57b
K-NH_4OAC (μg/g)	329a	250b
Ca-NH_4OAC (μg/g)	2380	2050
Mg-NH_4OAC (μg/g)	112a	95b
Cu-DTPA (μg/g)	2.6a	2.3a
Fe - DTPA (μg/g)	43.4a	24.5b
Zn- DTPA (μg/g)	2.1a	0.9b
Mn - DTPA (μg/g)	9.0a	4.3b

Mean in each row for each parameter, followed by the same letter, are not significantly different at the 0.05 level according to Duncan's new multiple range test

Table 3. Concentrations of non-essential elements in loamy sand soil treated with compost or inorganic fertilizer.

Elements (µg/g)	Treatments	
	Compost	Inorganic
Cd- DTPA	2.71a	1.29b
Cr- DTPA	34.21a	33.24a
Ni- DTPA	12.88a	12.02b
Pb- DTPA	14.05a	13.89a

level according to Duncan's new multiple range test Mean in each row for each element, followed by the same letter, are not significantly different at the 0.05

Despite their different effects upon soil pH (Table 2), the effects of compost and inorganic fertilizer upon the concentration of Cu were similar, compared to the findings for Zn and Mn. Addition of compost increased the levels of Cu, Zn, Mn and Pb as found previously in different soil types (Narwal and Singh, 1998 and Walker et al., 2003). Raising the soil organic matter content can increase soil CEC, a factor which may affect both soluble and exchangeable metal levels (Shuman, 1999 and Yoo and James, 2002). The effect of compost on heavy metal solubility also depends greatly upon the degree of humification of its OM and its effect upon soil pH (Narwal and Singh, 1998, Almas et al., 1999, Shuman, 1999 and Walker et al., 2003). However, in the current study, the effects of compost on soil pH seemed to be the main determinants of Zn and Mn availability and uptake. So, the pH effect was greater than that of metal complex formation by soluble OM.

The element concentrations were closely (inversely) related to soil pH (Table 4), reflecting earlier findings (Williamson and Johnson, 1981, Sanders, 1983 and Ross, 1994). The relationship was close for Zn and Mn than for Cu, perhaps because Cu levels in soil often are influenced more by OM than by pH, due to the ease with which Cu can be chelated by OM (Sanders, 1983, Sanders et al., 1986 and Ross, 1994).

The availability and plant uptake of Pb were reduced by compost. This may have been a consequence of the immobilization of Pb in the compost-treated soil (Ross, 1994 and Walker et al., 2003) and in the case of inorganic fertilizer, due to increased soil pH.

Table 4. Pearson correlation coefficients calculated for the relationships between elements concentration extractable from soil with DTPA (µg/g dry soil) and soil pH, shoot elements concentration ((µg/g DM) and soil pH and shoot elements concentration and soil element concentration extractable with DTPA.

Element	Pearson correlation coefficient [a]		
	[Shoot element] - [Soil element[a]]	[Shoot element] - [Soil pH [b]]	[Soil element] - [Soil pH[c]]
Cu	0.837***	- 0.882***	- 0.754***
Pb	0.416ns	- 0.913***	- 0.689***
Zn	0.982***	- 0.968***	- 0.977***
Fe	0.265ns	- 0.289ns	- 0.641***
Mn	0.938***	- 0.903***	- 0.897***

a, b, c = significance level: *** $p < 0.001$, ns $P \geq 0.05$

Table 5. Elements concentration in roots, leaves, stem and grains of alfalfa grown in compost or inorganic fertilizer treated soil.

Plant tissues	treatment	Elements												
		N	P	K	Ca	Mg	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
		%					µg/g							
Roots	Compost	1.19	1.19	1.25	0.58	0.23	-	-	27.5a	3965	126	-	-	50.3
	Inorganic fertilizer	1.02	1.18	1.28	0.56	0.20	-	-	16.8b	3670	121	-	-	48.5
Leaves	Compost	1.97	0.47a	1.89	0.82	0.19	0.027	0.389	16.2	401	134	0.059	0.234	37.9
	Inorganic fertilizer	2.09	0.23b	1.80	0.76	0.17	0.022	0.376	15.7	385	129	0.053	0.244	36.7
Stem	Compost	1.73	0.30a	3.05	0.63	0.26	0.023a	0.166	14.1	179	123	0.043	0.122	91.3
	Inorganic fertilizer	1.68	0.16b	2.98	0.58	0.25	0.013b	0.149	13.2	162	119	0.038	0.119	89.7
seeds	Compost	20.4	0.45	0.93	0.11	0.29	0.014	0.147	10.3	145	57.2a	0.091	0.123	44.8
	Inorganic fertilizer	2.10	0.42	0.87	0.09	0.27	0.011	0.142	9.70	139	30.8b	0.086	0.120	44.2

Mean in each column for each tissue, followed by the same letter, are not significantly different at the 0.05 level according to Duncan's new multiple range test.

Table 6. . Elements concentration in roots, leaves, stem and grains of Rhodas grass grown in compost or inorganic fertilizer treated soil.

Plant tissues	treatment	Elements												
		N	P	K	Ca	Mg	Cd	Cr	Cu	Fe	Mn	Ni	Pb	Zn
		%					μg/g							
Roots	Compost	1.16a	0.16a	0.28a	0.48	0.06	1.30	7.62a	4.13	806a	423a	3.54a	4.73a	35a
	Inorganic fertilizer	0.91b	0.04b	0.27	0.45	0.03	1.19	5.74b	3.06b	742b	291b	1.83b	2.18b	26b
Leaves	Compost	1.38a	0.40	0.32	0.30	0.23	0.19	0.21	2.93	110.1	373	1.15	0.72	16.0
	Inorganic fertilizer	1.27b	0.28	0.30	0.25	0.20	0.16	0.20	2.88	108.4	252	1.12	0.64	14.5
Stem	Compost	1.19	0.37	0.31	0.26	0.22	0.21	0.23	2.71	104.0	207	1.25	1.32	13.1
	Inorganic fertilizer	0.86	0.36	0.27	0.23	0.419	0.19	0.22	2.68	103.4	196	1.19	1.40	10.2
seeds	Compost	2.62	0.46a	0.34	0.09	0.13	0.08	0.19	2.94a	94.1	142	1.07a	0.72	15.0a
	Inorganic fertilizer	2.67	0.30b	0.31	0.07	0.12	0.06	0.17	2.46b	82.5	139	1.00b	0.69	12.0b

Mean in each column for each tissue, followed by the same letter, are not significantly different at the 0.05 level according to Duncan's new multiple range test.

Concentrations of elements in alfalfa fertilized with compost were not significantly different from those in alfalfa fertilized with inorganic fertilizer (Table 5). Except for phosphorus in leaves and stems of plants grown with compost which was significantly higher than in those grown with inorganic fertilizer. Seeds from alfalfa treated with compost had significantly more Mn than the inorganically fertilized seeds. Stems grown with compost had more significantly Cd than those grown with inorganic fertilizer. Roots with compost had significantly more metals than control roots.

Except for K, Ca, Mg and Cd, roots of Rhodes grass composts had significantly higher concentrations of all elements than roots grown with inorganic fertilizer (Table 6). The leaves of compost treatments had significantly higher content of N only than leaves grown with inorganic fertilizer (Table 6). The effect of the treatments had similar in other elemental concentrations. Stem from the both two treatments of treated plants were similar in concentration of elements. Grains from the inorganic fertilizer and compost treated plants were similar in elemental concentration, except for P, Cu, Ni and Zn, which were significantly higher in grains from the compost treated plants, in grains than from the inorganically fertilized plants.

CONCLUSION

Concentrations of essential and non-essential elements in plants grown with compost were similar to the concentrations of these elements in plants grown with inorganic fertilizer. Nickel was the only non-essential element of concern in compost which occurred in higher concentrations in the grains than in the grains of inorganically fertilized plants. But the concentration of Ni in the grains from plants grown with compost was within ranges observed in plants not grown with compost. Therefore, the results indicated that pruning waste is an effective method of fertilization with minimal transfer of non-essential elements from soil to plants.

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الملخص العربي

تأثير مخلفات التقليم المكمورة علي المحتوي المعدني للتربة والبرسيم الحجازي (*Medicago sativa* L.) وحشيشة الرودس (*Chloris gayana* L.)

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يهدف هذا البحث الي تقدير كمية العناصر الثقيلة و المهمة الممتصة بواسطة نباتي البرسيم الحجازي (*Medicago sativa* L.) وحشيشة الرودس (*Chloris gayana* L.) النامية في تربة معاملة بكمبوست (سماد عضوي من مخلفات تقليم النباتات النامية في منطقة البستان بالنوبارية). أجريت هذه التجربة في منطقة البستان في احواض اسمنتية مجهزة (Lysimeters) .عوملت التربة بالسماد المعدني (شاهد) و بالكمبوست بمجموع ٣٢ طن كمبوست للهكتار في السنة خلال عام ٢٠٠٤م وزرعت نباتات البرسيم الحجازي وحشيشة الرودس. جمعت عينات التربة وعينات النباتات من كل المعاملات. قدرت اربعة معادن ثقيلة (Cd, Cr, Ni, Pb) بالاضافة الي تسعة عناصر غذائية ضرورية (N, P, K, Ca, Mg, Cu, Fe, Mn, Zn).

وجد أن الترب المعاملة بالكمبوست تحتوي علي تركيزات اعلي من العناصر N, P, K, Ca, Fe, Cu, Fe, Mn, Zn, Cd, Cr, Ni, Mg, من الترب المعاملة بالسماد المعدني. كذلك وجد أن تركيزات العناصر الغذائية الضرورية في النباتات النامية في التربة المعاملة بالكمبوست مشابها لتركيزات هذه العناضر في النباتات المعاملة بالسماد المعدني. وقد كان تراكم العناصر الثقيلة متماثلة في النباتات تحت تأثير هذه المعاملات ماعد عنصرا Cd في سيقان البرسيم الحجازي، وعنصر Cr في سيقان حشيشة الرودس، وعنصر Ni في جذور وبذور حشيشة الرودس وعنصر الرصاص في جذور حشيشة الرودس بينما كان تركيز عنصر النيكل في بذور حشيشة الرودس النامي بمعاملة الكمبوست في مدي التركيزات العادية. كان مستوي عنصر الكادميوم منخفض في كل النباتات وهذا يشير الي في حالة إضافة الكمبوست للتربة فأن انتقال عنصر الكادميوم من التربة الي النبات يكون قليل. ومن هنا نشير الي أن أضافة كمبوست مخلفات التقليم النباتية هي طريقة فعالة في تسميد النباتاز