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Observation of plant development with compost, lime and chemical fertilizer support in acidic soil with high metal content

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Abstract

In this study, the growth of parsley plants (Petroselinum crispum) was observed in an acidic (pH 2) soil having high heavy metal concentrations with the addition of compost, lime and chemical fertilizer as soil amendments. The soil sample was obtained from the Kastel Village of the Çamburnu district in Trabzon. The compost used as soil conditioner was attained from the Kemerburgaz Recycling and Composting Facility located in Istanbul. Calcium ammonium nitrate was used as chemical fertilizer. Soil samples were prepared to contain i. 10% (v/v) compost (K1), ii. 10% (v/v) compost and 1.5% (v/v) chemical fertilizer (K2), iii. 10% (v/v) compost and 1.5% (v/v) lime (K3) iv. 1.5% (v/v) lime and 1.5% (v/v) chemical fertilizer (K4), v. 10% (v/v) compost, 1.5% (v/v) lime and 1.5% (v/v) chemical fertilizer (K5) and vi. 10% (v/v) compost and 1.5% (v/v) chemical fertilizer. The addition of chemical fertilizer was performed simultaneously with the plantation of parsley seeds. Also, plant seeds were planted in the both of the soil samples with no additives as a control samples. The prepared plant pots were placed in an artificially lighted environment with timer control obtaining 16 hours daylight, 8 hours night. Lengths and weights of root and aerial parts of parsley plants were measured at the end of the growth period. The pH of the soil mixtures in the plant pots were measured at the beginning and end of the experiment. At the end of the study, plant growth was not observed in the acidic soil sample in the absence of soil amendments. The best plant growth (aerial part length 18.6 cm, root length 4 cm, weight 0.2 g) was achieved in commercial plant soil containing ammonium nitrate. The appropriate plant growth (aerial part length 11 cm, root length 4 cm, weight 0.053 g) for the acidic and heavy metal containing soil were reached with the sample containing 10% (v/v) compost, 1.5% (v/v) lime and 1.5% (v/v) chemical fertilizer.

Keywords: MSW compost, Soil, Heavy metals, Soil remediation

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Introduction

It is known that the amount of harmful compounds in the environment is increasing along with the rapid rise of technology and industrial agriculture (Neilson and Rajakaruna, 2015). Factors such as industrial wastes, leachate, sewage sludge, mining and use of excessive fertilizer and pesticides are the main sources of harmful pollutants in soil and water environment (Memon et al., 2001; Järup, 2003). Organic and inorganic pollutants containing heavy metals are known as the most important pollutants causing environmental pollution. Unlike other types of pollution, heavy metals are in the high risk group for ecosystems due to their bioaccumulation and their resistance to chemical and biological degradation. Mercury (Hg), Cadmium (Cd), Copper (Cu), Manganese (Mn), Zinc (Zn) and Aluminum (Al) are the most commonly found heavy metals in the environment (Ullah et al., 2015). The presence of heavy metals in soil, especially in agricultural soils, poses a great danger to human health and the ecosystem (Zhuang et al., 2009; ; Luo et al., 2011; Sayara et al., 2011; Colin et al., 2012; Sultana et al., 2014; Aryal et al., 2016; ; Nirola et al., 2016; Zhou et al., 2017). Stabilization of heavy metals in the soil is regarded as a remarkable alternative to heavy metal removal due to its efficiency, short duration of action, more economical compared to other remediation methods, and the low efficacy on ecosystem (Kumpiene et al., 2008; Lee et al., 2009; Zhou et al., 2017). For this reason, stabilization studies carried out by application of soil amendments such as compost, lime and biochar to the soil system containing high amounts of heavy metals are frequently encountered in the literature (White et al., 1995; Gray et al., 2006; Shi et al., 2009; Du et al., 2010; Ruyters et al.,2011; Bolan et al., 2014; Ding et al., 2016; Huang et al., 2016; Li et al., 2016; Wang et al., 2016;; Xu et al., 2016).

Approximately 50% reduction in volume and in weight of domestic solid wastes is maintained by composting. Therefore, it is known as an effective and environmental friendly waste treatment method. The use of the obtained compost as a soil remediation material in agricultural areas is also an important environmental advantage (Zhang, 2013).

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Composting process is defined as a biochemical breakdown of organic parts of agricultural and urban solid wastes by bacteria and other microorganisms into humus. Compost is a soil conditioner and not a fertilizer. In contrast to chemical fertilizers, dissolution of compost materials can occur in a long time and its transportation to receiving organisms also takes time (Uygun, 2012). Composting is a significant part of modern integrated solid waste management. A valuable product with high humus content for various usage is obtained by composting method. The amount of solid wastes for landfilling is being reduced and organic wastes can be recovered in this way. The compost is mainly used for agricultural activities. In addition, it is frequently used in plantation, horticulture, public parks, golf areas and landscaping. The addition of lime to the soil increases the pH of soil and the conversion of heavy metals in soil to stationary forms by the effects of this pH increase have been asserted in many studies in the literature (Zhu et al., 2010; Mahar et al., 2015; Yan-bing et al., 2017).

In this study, it is aimed to observe the growth of the parsley plants in soils having highly acidic character and high heavy metal concentration by addition of soil amendments such as compost, lime and chemical fertilizer. For this purpose, experiments were carried out in plant pots in laboratory environment.

Materials and Methods

The first soil sample (T1) was obtained from the Kastel Village on the border of Çamburnu District of Trabzon. Also, a commercial plant soil (T2) (Tropical brand, soil for ornamental plants) was used and the growth of plants was examined on two soil samples. The compost sample used as soil conditioner was obtained from the Kemerburgaz Recycling and Composting Facility located in Istanbul Metropolitan Municipality. Calcium ammonium nitrate (Total nitrogen 26%, Ammonium nitrogen 13%, Nitrate nitrogen 13%) was employed as an chemical fertilizer. The addition of lime was carried out with slaked lime ($Ca(OH)_2$).

For the pH measurement of compost, distilled water was added to the compost sample in a ratio of 1/5 (e.g.: 2 g sample/10 mL distilled water), and the pH was measuredwith the pH meter after mixing for 10 minutes by magnetic stirrer (Methodenbuch zur Analyse von Kompost, 1994). In order to determine the pH value of the soil sample, 0.1 N KCl was added on the soil sample in a ratio of 1/2.5 and the pH value was read with the pH meter after mixing for 1 hour on the magnetic stirrer (Paradelo at al., 2011). The pH measurements were done by using Jenway 3040 Ion Analyzer. The C, H, N values of the soil and compost samples were determined using Thermo Scientific Flash 2000 CHN-S elemental analyzer.

Samples were prepared for analysis by the microwave digestion method (U.S. EPA, 2007) for identification of metal quantities in soil and compost samples. After the microwave digestion, the samples were filtered (with MN 640, 125 mm, Macherey-Nagel filter paper) and poured into HDPE balloons and volumes were fulfilled with ultrapure water to 50 mL. Analyses of the samples were performed with an ICP optical emission spectrometer (Perkin Elmer Optima 7000 DV) combined with an automatic sampler (Perkin Elmer S10 Autosampler).

Inorder to observe the plant growth , the mixtures to be placed in the plant pots were prepared as follows. T1 soil samples were prepared to contain (i) 10% (v/v) compost (K1), (ii) 10% (v/v) compost and 1.5% (v/v) chemical fertilizer (K2), (iii) 10% (v/v) compost and 1.5% (v/v) lime (K3) (iv) 1.5% (v/v) lime and 1.5% (v/v) chemical fertilizer (K4), (v) 10% (v/v) compost, 1.5% (v/v) lime and 1.5% (v/v) chemical fertilizer (K5) and (vi) 10% (v/v) compost and 1.5% (v/v) chemical fertilizer (K6).

Two weeks waiting period was applied prior to the addition of chemical fertilizer, to obtain reaction between compost, T1 sample and lime. Only irrigation was done at this stage. Moreover, the mixture prepared by 1.5 % (v/v) chemical fertilizer addition to T2 soil without any other conditioner addition were placed in the plant pots. Then, when parsley seeds were planted, the chemical fertilizer was added simultaneously. Seeds also were planted into the plant pots having no soil additives as control samples. The prepared pots were placed in an artificially lighted environment with timer control obtaining 16 hours daylight, 8 hours night. The temperature was kept constant during experimental period. The plants were harvested after 40 days. All experiments were replicated and mean values and standard deviations were presented.

Results and Discussion

The characterization of the compost and soil samples used in the experiments is presented in Table 1. According to Table 1, it is seen that T1 soil is acidic (pH 2) and the pH value of T2 soil is about 7. When C, H, N values are examined, it is seen that T1 soil has very low amount of C as 0.1% and N content is not detected in the samples. The C and N contents of T2 soil were determined as 3.42 % and 5.45 %, respectively. The pH of compost was determined as 7.9.

When the values in Table 2 are compared with the values in Table 1, it is seen that the pH value of T1 sample is defined as "toxic for all products". The pH value of the T2 sample is defined as "all products grow". When the values in Table 1 are compared with the values in Table 3, it can be seen that the compost used in the study provides the quality parameters in the "Compost Regulation". When the values in Table 1 are compared with those in Table 4, it is seen that the amounts of metals in T1 were found much higher than the limit values given in Table 4.

Root and aerial part lengths of growing parsley plants were measured after a period of 40 days. Their weights were recorded. The pH values of the mixture in the plant pots were measured at the beginning and at the end of the experiment. The short nomenclature of the samples and the pH values at the beginning and at the end of the study are presented in Table 5. According to results given in Table 5, the pH increases from 2 to 5 with the addition of 10% compost to T1 soil, and when 1.5% lime is added, the pH increases from 2 to 7. It is known that the proper pH value for parsley plants changes between 5-8. With the addition of compost and lime, the pH value of T1 soil is reached to a proper pH value for the development of parsley plant.

Root and stem lengths of harvested plants at the end of the 40-day growth period are displayed in Table 6. According to the Table 6, plant growth was not observed in plant pots containing only T1 soil, K1 and K2 mixtures. Although the pH values of the mixtures K1 and K2 were initially at the appropriate pH for the development of the parsley plant, it was considered that the reason of the observation of no plant growth can be the decrease in pH up to 4 (pH 4 in Table 1 is defined as toxic to most crops) at the end of the experiment. The plant growth (9.5 cm stem length, 2.5 cm root length, 0.00328 g weight) was observed even with only the addition of lime to the T1 soil (K3 mixture). The pH of K3 mixture was recorded as 6 at the end of the study. This pH value is defined as appropriate for the growth of all products in Table 1. Besides the lime, the addition of chemical fertilizer (K4 mixture) and, compost and chemical fertilizer (K5 mixture) to T1 soil improved the growth of parsley plants, especially it was resulted in an increase in their weights (Table 6).

Based on the K4 and K5 mixtures, it is considered that the addition of compost improves the porosity of the soil as well as the adjusting the pH for the plant growth, and the elimination of nutrient deficiency by using chemical fertilizer affect plant growth positively. Table 6 shows that the best plant growth was achieved in the mixture (K6) with fertilizer added to the T2 soil. However, it can be said that the results obtained from the experiments of K4 and K5 mixtures were lead to better plant growth than the results of experiments performed with only T2 soil (Table 6).

Conclusion

In this study, the growth of parsley plant was achieved in an acidic soil having high metal content by adding lime, compost and chemical fertilizer to the soil. Addition of only compost as a soil conditioner was not found sufficient and the addition of both lime and compost was suggested to buffer the acidity of the soil. Also, the addition of chemical fertilizer was promoted elimination of nutrient deficiency of the soil. Thus, the best conditions for the parsley plant growth in acidic soil have been determined as use of a combination of compost, lime and chemical fertilizer. As well as monitoring the plant growth in this type acidic and heavy metal containing soils, the accumulation of the heavy metals in roots and aerial parts of the grown plants was thought to be investigated as a future work with a longer study period.

Table1. Characterization of compost and soil samples

Parameters	Units	Compost	T1	T2
pH		7.9±0.01	2±0.02	7.00±0.01
C	%	11±2.11	0.1±0.001	3.42±0.002
N	%	0.4 ±0.001	-	0.545±0.001
C/N		28±1.03	-	6±0.03
H	%	-	0.75±0.002	0.95±1.03
Ni	mg/kg	36±1.05	20.14±0.09	2±0.001
Fe	mg/kg	11000±2.44	4165±1.12	5200±1.04
Cu	mg/kg	200±0.2	3515±1.44	48.89±0.05
Cd	mg/kg	1±0.001	134±0.005	ND
Zn	mg/kg	380±0.02	25901±0.22	125±0.01
Pb	mg/kg	80±0.1	3553±0.12	ND
Mn	mg/kg	320±0.015	140±0.01	110±0.02

±SD (Standard deviation), ND: Not detected

Table2. Relation between pH values and plant growth

pH	Soil reaction	Effects to products
3	Very high acidity	Toxic to all products
4	Strong acidity	Too toxic to most products
5	Moderate acidity	Toxic to some products
6	Light acidity	All products grow
7	Neutral	All products grow
8	Light alkaline	Most products grow
9	Medium alkaline	Toxic for many products
10	Strong alkaline	Toxic for all products

Table3. Compost quality parameters (Compost Notification, 2015)

Parameters	Values
pH	5.5-8.5
C/N	10-30
Copper (mg/kg)	450
Zinc (mg/kg)	1100
Cadmium (mg/kg)	3
Lead (mg/kg)	150
Nickel (mg/kg)	120

Table 4. Generic Pollutant Limit Values (TKKNY , 2010)

Pollutant	Absorption by ingestion of soil and skin contact (mg/kg oven dry soil)	Inhalation of volatile substances (mg/kg oven dry soil)	Inhalation of fugitive dusts in the external environment (mg/kg oven dry soil)	Transport of pollutants to groundwater and drinking of that groundwater[1] (mg/kg oven dry soil)	
				SF = 10	SF = 1
Copper	3129	-	-	514	51
Zinc	23464	-	-	6811	681
Cadmium	70	-	1124	27	3
Lead	400	-	-	135	14
Nickel	1564	-	-	13	1

Table5. pH values of the soil mixtures in the pots at the beginning and end of the study

Sample name	Sample code	Initial pH	Final pH
Soil in acidic form	T1	2±0.01	2±0.01
Commercial plant soil	T2	7±0.015	6±0.02
T1+10 % compost	K1	5±0.01	4±0.01
T1+10 % compost+%1.5 chemical fertilizer	K2	5±0.012	4±0.014
T1+1.5 % lime	K3	7±0.021	6±0.01
T1+1.5 % lime+1.5 % chemical fertilizer	K4	7±0.01	7±0.011
T1+10 % compost+1.5 % lime + %1.5 chemical fertilizer	K5	7±0.013	7±0.001
T2+1.5 % chemical fertilizer	K6	7±0.002	6±0.01

±SD (Standard deviation)

Table6. Growth of plants at the end of the study

Sample code	Stem length (cm)	Root length (cm)	Stem weight (g)
T1	-*	-	-
T2	8±0.001	4±0.001	0.0345±0.0002
K1	-	-	-
K2	-	-	-
K3	9.5±0.002	2.5±0.0001	0.00328±0.00001
K4	10±0.0011	4±0.001	0.04335±0.000012
K5	11±0.001	4±0.0013	0.0532±0.00001
K6	18.6±0.01	4±0.0012	0.2011±0.00001

* Plant growth was not observed, ±SD (Standard deviation)

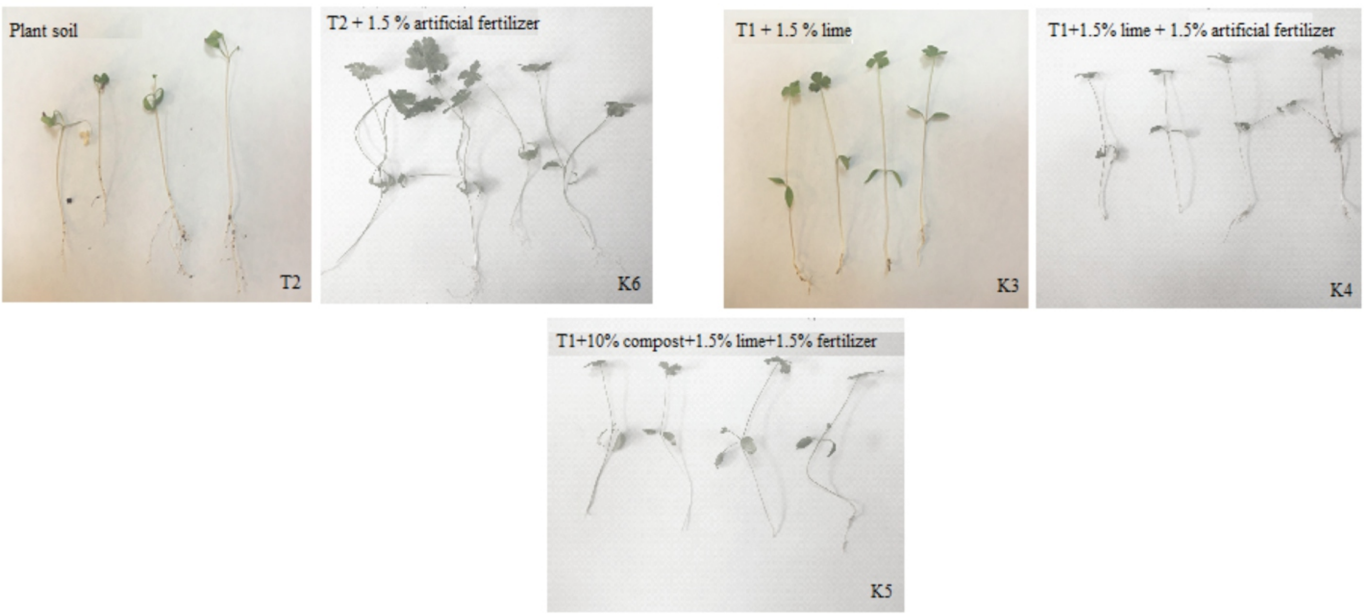

Figure1. Photos of plants developed at the end of the study

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