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INFLUENCE OF WOOD VERMICOMPOST ON SOME SOIL AND PLANT PROPERTIES OF COAL MINE TAILINGS (TERTIARY SAND) IN LUSATIAN LIGNITE REGION (EASTERN GERMANY)

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Abstract: One of the most negative site effects of open-cast mining in Germany is the large area of post coal mining tailings dumps which have to be reclaimed and restored to an acceptable condition. This study was carried out to evaluate the effect of different application rates of wood vermicompost on soil physiochemical properties and on some growth parameters of a *RSM* grass in tertiary sand substrates. The experiment was carried using plastic pots in a greenhouse for a period of 42 days. Soil samples were collected from different localities at depth (0-30 cm) and then mixed well to make a representative sample of the site. The representative soil sample was mixed in completely randomize design with the wood vermicompost at mixing ratios of 0.0, 3.0, 12.5 and 25.0 % (based on weight) and then sown with *RSM* grass seeds. At the end of experiment the data showed that physical properties such as water holding capacity, bulk density and total porosity in soil ameliorated with vermicompost were improved. Most soil chemical properties were increased significantly with the increase of vermicompost application rates particularly soil reaction, electrical conductivity, organic matter content, total nitrogen, total carbon, total sulphur, soil buffering capacity and soil available elements content (except Fe). The soils treated with vermicompost had significantly more potential and effective cation exchange capacity and base saturation percentage in comparison to unameliorated soil. On the contrary, total exchangeable acidity was decreased with the increase of vermicompost rates. Compared with the control treatment, the treated soil with vermicompost had significant increase in grass biomass (fresh and dry matter yield) as well as enhancing plant uptake of macro-micro-nutrients. The results of this experiment revealed that addition of wood vermicompost had significant positive effects on the soil physical and chemical properties, which affected the response of plant.

Key Words: Open-cast lignite mining, Lusatian tertiary sand, Soil amelioration, Reclamation, Recultivation, Wood vermicompost

1. INTRODUCTION

Open-cast lignite (brown coal) mining operations in the Lusatian District in eastern Germany (fig, 1) have created an area of almost 1000 km^2 covered by spoil heaps of clastic overburden sediments, of tertiary and quaternary age (Huettl and Weber, 2001). These spoil heap sediments often abound in lignitic components in the form of coal fragments or as coal dust (Neumann, 1999). The post-lignite mining landscape is dominated by sandy substrates of Tertiary and Quaternary sediments. These substrates can be identified as: lignite- and pyrite-containing substrates stemming from Tertiary sediments and lignite- and pyrite-free substrates stemming from Quaternary sediments.

The majority of these substrates are pure sands and loamy sands (Katzur and Haubold-Rosar, 1996). The pyrite content in these substrates when exposed to the atmosphere leads to a high potential for acid production and consequently very phytotoxic site conditions. Sulphuric acid is formed and mobilized in these raw soils during the chemical weathering of the sulphide minerals (marcasite and pyrite). This causes an extreme acid soil reaction (Claus, 2003).These sediments are extremely acid (2.5 - 3) and can contain up to 50 g kg^{-1} carbon derived from lignite (Huettl and Weber, 2001). Other negative properties are reduced wettability of the soil, low nutrient content and pedogenic organic matter, insufficient soil life and disturbed air-water balances. Reduced infiltration hinders plant growth as soil water is not renewed (Wang et al., 2000). Therefore, it is often difficult to initiate plant growth in the post mining landscape. It is even more difficult to achieve successful recultivation in the sense of establishing new agricultural and forest ecosystems that can be used by man as it was the case before mining.

For successful reclamation, high application amounts of basic materials are required to neutralize soil acidity and hence create the potential for plant growth. Due to the lack of nutrients in these spoil substrates mineral fertilizers are conventionally applied as a fundamental reclamation measure. Because of the sandy texture of these spoil substrates the risk of nutrient losses from the mineral fertilizers via seepage water leaching is relatively high (Wilden, 2000). An alternative treatment to the addition of mineral fertilizers might be the application of organic residues like compost or sewage sludge (Wilden et al., 2001). The main effects are the improvement of the soil structure by increasing porosity and reducing the bulk density of an ameliorated soil, the improvement of soil aeration, water-holding capacity, buffer capacity and cation exchange capacity (Lynch et al., 2005). The addition of compost to the soil with a more humified organic matter leads to longer lasting effects of this organic matter in the soil, increasing the agricultural value of the composts. Polysaccharides and other polymeric substances present in organic matter act as aggregating compounds (Masciandaro et al., 2000) and increase micropores in the soil. Recently, Pandey and Shukla (2006) studied the effect of composted yard waste on the movement water in a sandy soil found that water and P retention in the soil was increased. Speir et al. (2004) reported that in samples from a field trial, soil total C, N, P and Olsen P were increased markedly with increasing compost application rate. Cation exchange capacity, exchangeable cations as will as total–extractable and EDTA – extractable metals (Cd, Cr, Cu, Ni, Pb and Zn) were also elevated. However, the total Cu reached to the allowable limit in biosolids compost amended soil. The physical properties of the ameliorated soils were improved in all cases as far as the saturated and unsaturated hydraulic conductivity, water retention capacity, bulk density, total porosity, pore size distribution, soil resistance to penetration, aggregation and aggregate stability, were concerned (Aggelides and Londra (2000). Composted organic matter can act as a liming agent in agricultural soils. Neutral to slightly alkaline composts can increase the pH in most acid soils, reducing the potential for Al and Mn toxicity (McConnell et al., 1994). Increases in pH are directly proportional to the proton and Al consumption capacity of the OM, specifically of humic and fulvic substances containing high carboxyl, phenolic, and enolic functional groups. As organic anions are adsorbed, a corresponding release of hydroxyls raises the pH of the soil. Vermicompost contains most nutrients in plant-available forms such as nitrates, phosphates, and exchangeable calcium and soluble potassium (Arancon et al., 2004 and Asciutto et al., 2006**)**. The addition of vermicompost to soils resulted in improved soil buffering capacity and the physical properties such as bulk density and total porosity. Vermicompost had significant positive effects on the soil chemical, physical properties (Rasool et al., 2008). With respect to total porosity, Wanas and Omran (2006) declared increasing the values of it as a result of applied compost.

The aim of this study was to evaluate some soil physio-chemical properties, availability of soil nutrients and determine some growth parameters of a *RSM* grass after different application rates of vermicompost produced from wood.

2. MATERIAL AND METHODS

Pot experiment was carried out in greenhouse using plastic pots of 18.7 cm diameter and 21.8 cm which filled with a mixture of vermicompost and coal mines tailings (tertiary sand). Soil sample was taken from the surface layer of tailings dumps (0-30 cm) in the Lusatian region. The samples were collected from different places and then mixed well to make a representative sample of the site (figure, 1). The representative soil sample was air-dried, ground and sieved through a 2 mm sieve. Chemical properties of this soil were analyzed according to standard methods and the resulting data is presented in Table (1).

The vermicompost used in the study was produced by mixing different ratios of woodchips (*Quercus rubra*) and lake mud to which two species of earthworms were introduced in plastic pots covered by nets for two months after co-composting for one month. At the end of vermicomposting trial (3 months) different compost treatments were mixed and sieved through a 2 mm sieve. The analysis of the used compost was listed in Table (1).The used soil was mixed with the prepared wood vermicompost at mixing ratios of 0.0, 3.0, 12.5 and 25.0 % (w/w). Eight pots for each mixing ratio were filled to a depth of 18 cm. The pots were arranged in completely plots randomize design.

Each pot was sowed by 0.4 g seeds of RSM 7.2.1.grass mixed from 45% *Festuca ovina duriuscula*, 10% *Festuca rubra commutata*, 15% *Festuca rubra rubra*, 15% *Festuca rubra trichophylla* and 15% *Lolium perenne*. This grass was used in the operating plan of closure of company LMBV, that they use it as standard - sowing for the dry region, the optimum quantity for this type of grass is 20 g m^{-2}. The pots were irrigated to 60 % water holding capacity for each treatment using tap water every 3 days.

At the end of the experiment (42 days from sowing), the plants in each pot were harvested. The harvested plants were washed with water until free from any soil particles. The plants of each pot (roots and straw) were weighted to measure the fresh weight, after straw separated from the roots. The plants were then initially air-dried then oven dried at 70 ^{0}C for 48 hr to obtain data on dry matter yield, they were then ground and kept for chemical analysis. The soil in each pot after harvesting was sampled, air-dried, ground, crushed, sieved through a 2 mm sieve and kept for different chemical and physical analysis. The methods of soil and vermicompost analysis are summarized in Table 1. Moreover, soil acid-base buffering capacity was measured and buffer curves were drawn, according to Arrhenius with Brenner and Kappen modification (Ostrowska et al., 1991), by adding increasing amounts of 0.1 mol HCl dm^{-3} and 0.1 mol NaOH dm^{-3} to soil samples, which, after 24 hours, was followed by potentiometric pH measurements. Total exchangeable acidity, potential and effective cation exchange capacity is due to the high amount of $CaCO_3$ in the compost and soil these were determined by 0.1M $BaCl_2$ methods (Table1). The total content of macro-micro nutrients (P, K, Ca, Mg, Fe, Cu, Zn, and Mn) were extracted by digesting 0.2 g of plants in all treatments at the end of experimental period with 10 ml of H_2SO_4-$HClO_4$ acid with a Conc. 3:1 (v/v) mixture until the digestion solution became colorless (Jackson, 1967). The available macro-micro nutrients were extracted according to methods listed in Table (1). Both the digestion and extracted solution were tested for macro-micro nutrients using atomic absorption spectrometry (AAS 1100B Perkin-Elmer) according the methods described by Havezov (1996) with the exception of phosphorus which was measured using a spectrophotometer. Relative increase (R_I, %) and its agronomic efficiency (A_E) of both the straw and roots of the plants were calculated using the following formulas (1 and 2), where R_T = Fresh or dry matter yield weight of treated plants, R_C = Fresh or dry matter yield weight of control, AT = Fresh or dry matter yield weight of treated plants, A_C = Fresh or dry matter yield weight of control, and P = Application rate of vermicompost (%).

$$R_I = 100(R_T - R_C)/R_C \qquad (1)$$

$$A_E = (A_T - A_C)/P \qquad (2)$$

All determinations of chemical, physical and plant attributes were carried out in three replicates which were measured on a dry weight basis. The data were statistically analyzed according to the method described by Snedecor and Cochran (1990). LSD range test was used to compare between the treatments means. The mean values within each column followed by same letters are not significantly different at 5% level of probability.

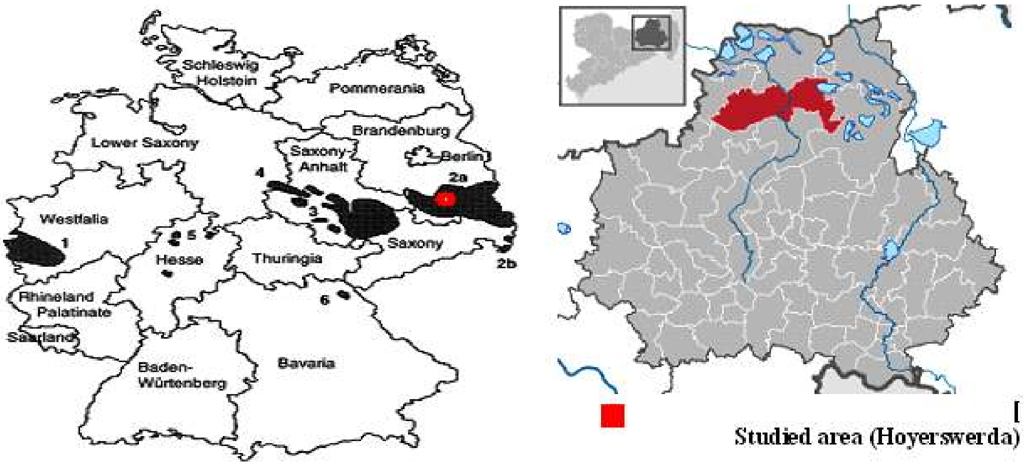

Figure 1. Location of Lusatian lignite mining regions (2a, 2b)

Table 1. Some physical and chemical properties of the studied soil and the used vermicompost

Properties	Soil	VC^{13}	Unit	Reference	Properties	Soil	VC^{13}	Unit	Reference
WHC^{1}	30.00	190.00	%	Dewis; Freites (1970)[11]	OM^{14}	2.43	27.18	%	DIN (2000)[13]
DBD^{2}	1.34	0.56	g cm^{-3}	Blake (1965)[4]	TOC^{15}	1.22	13.59		Nelson; Sommers (1996)[28]
DPD^{3}	2.4	1.47		Blake; Hartge (1986b)[5]	TS^{16}	0.22	0.76		Tabatabai; Bremner (1991)[39]
TP^{4}	44.17	61.9	%	-	TC^{17}	12.4	150.5	g kg^{-1}	
EC^{5}	0.19	3.19	dSm^{-1}	DIN ISO (1997)[14]	TN^{18}	0.4	12.5		
pH^{6}	3.04	7.48	-	DINISO (2002) [15]	C/N ratio	31	12.04	-	
EB^{7} Ca^{++}	0.75	22.05	cmol kg^{-1}	Hendershot; Duquette (1986)[18]	Available nutrients KCl-N	15.42	3309.17	mg kg^{-1}	Dahnke(1990)[10]
Mg^{++}	0.69	7.75			Bray^{1} P	7.59	39.65		Bray; Kurtz (1945)[6]
K^{+}	0.6	7.67			Available -EDTA K	187.86	975.34		Cottenie et al. (1982)[8]
Na^{+}	0.57	6.11			Ca	322.13	2400.3		
TEB^{8}	2.61	43.58			Mg	253.54	813.7		
TEA^{9}	0.54	0.64		Expert Panel on Soil(2003)[16]	Fe	745.25	244		
ECEC^{10}	3.15	44.22		-	Cu	0.5	1.5		
PCEC^{11}	3.45	48.01		[21]	Zn	1	19		
BS^{12}	82.86	98.55	%	-	Mn	0.9	77		

Abbreviations: 1 = Water holding capacity, 2 = Dry bulk density, 3 = Dry particle density, 4 = Total porosity ((DPD-DBD)/DPD) x100), 5= measured in (1:5, w/v) dist. water extraction solution, 6= measured in 0.01M $CaCl_2$ extraction solution (1:5, w/v), 7= Exchangeable bases, 8= total exchangeable bases, 9=Total exchangeable acidity, 10=Effective cation exchange capacity (TEB+TEA), 11=Potential cation exchange capacity, 12= Bases saturation percentage (TEB/ ECEC) x 100), 13= Vermicompost, 14=Organic matter, 15=Total organic carbon, 16=Total sulphur, 17=Total carbon, 18=Total nitrogen.

3. RESULTS AND DISCUSSION

3.1. Effect of Vermicompost on Soil Physical Properties

Data presented in Table (2) show that, different application rates of vermicompost (VAR) affected on different soil physical properties. Soil water holding capacity (WHC, %) and total porosity (TP, %) were positively influenced, and the treatments can be ordered as follow: 0.0>3.0>12.5>25.0 % vermicompost mix ratio. The highest percentage of WHC and TP were found with 25.0 % compost application rate while the lowest was observed in the treatment free from compost. These trends can be explained as follows; when the compost is mixed with soils it binds to the soil particles forming larger particles that now have larger air spaces between them. The data in Table (2), shows that bulk density (BD) and particle density (PD) were decreased with an increased rate of compost application. The lowest value of both BD and PD were found in the treatment with 25.0 % compost, whereas the highest value was noted in control treatment. It can be concluded that, composted organic matter improves soil structure by reducing the potential for soil compaction. The present results are supported by other studies (Wanas and Omran 2006; Aggelides and Londra, 2000).

3.2. Effect of Vermicompost on Soil Chemical Properties

The data presented in Table (3) shows that different application rates of vermicompost had positive effects on different soil chemical properties, with the exception of the C/N ratio, which decreased with an increase in compost application rate. The value of electric conductivity (EC, dSm^{-1}) increased significantly with an increase in the rate of compost application; this trend may be due to the high amount of nutrients in the applied compost. Soil pH was significantly raised by increasing the application rate of vermicompost. This trend may be the result of the high base content in the compost and its large capacity to absorb free protons (H^+) in the soils, this result is similar to that reported by Cox et al., 2001. In addition, data in Table (3) shows that, the amounts of total organic carbon (TOC), organic matter (OM), total carbon (TC) and total sulphur (TS) increased significantly with an increase in vermicompost application rate, with exception of the 3.0 % addition which was insignificant compared to control treatment. With different application rates of vermicompost the total nitrogen (TN) increased significantly, while the C/N ratio gave contrasting values when increasing vermicompost application rate. These results are in agreement with the results obtained by Renato et al., 2003 and Rasool et al., 2008.

3.3. Effect of Vermicompost on CEC and TEA

Regarding the data in Table (4), it can shown that the exchangeable bases are increased significantly with the increase in vermicompost application rate (with the exception of K and Na at an addition rate 3 %, where the increase was not significant in comparison with control treatment). The highest increase in value was recorded for Ca followed by Mg, K, and Na. The highest amount of exchangeable cations occurred in the 25.0 % compost treatment, whereas the lowest amount of exchangeable cations were recorded in the control. The summation of exchangeable bases shows the same trend. In addition, the data in Table (4) show that increasing compost application rate led to decreased total exchangeable acidity. The data showed that, the highest value for this parameter was in the control (0.52 cmol kg^{-1}) and lowest value was in the soil treated with 25 % compost (0.20 cmol kg^{-1}). This trend may be due to the reaction of the compost with the exchangeable acids reducing their activity (Wong et al., 1998). The effective and potential cation exchange capacity (ECEC and PCEC) and, in consequence, the base saturation percentage (BS) were significantly increased with the increase in vermicompost application rate. Similar results were reported by McConnell et al. (1994).

3.4. Effect of Vermicompost on Soil Acid-Base Buffering Capacity

Soil acid and base buffering capacities can be expressed by the slope of buffer curves, according to the algebraic equation (3), where x_2 and x_1 are the volume (ml) 16 and zero (100 ml dist water) respectively of HCl or NaOH added to sample, y_2 and y_1 are the pH of sample after adding 16 and zero ml respectively of HCl or NaOH.

$$Slope = (y_2 - y_1)/(x_2 - x_1) \qquad (3)$$

The data illustrated in Fig (2) and the values of the curve slopes (buffering capacity) in Table (5) show that, an increase in the independent HCl and NaOH factor caused a decrease and or increase in the dependent factor (pH) respectively. Generally, rates of change with the addition of acid were lower than with the addition of alkali, due to the presence of a high proportion of carbon in the soil (Table, 1). In the present work, the experimental soil (control) showed low resistance to alkalization and acidification; the addition of an alkali (NaOH) caused pH changes which varied between 4.23 and 10.13 and on the addition of an acidifying agent (HCl) the pH changed from 4.23 to 2.24. Similarly, considerable changes in the curve slopes were recorded in the soil treated with 3.0 % vermicompost. The addition of HCl and NaOH, caused a 1.60-unit pH decrease and 5.45-unit pH increase respectively. On the other hand, the addition of vermicompost increased soil resistance to change in pH, the highest resistance was recorded for the treatments with higher addition rates of vermicompost (12.5 and 25 %). The difference between the impact of 12.5 and 25.0 % rate of compost, expressed by small area between the two curves, was very little. Treatments with 12.5 and 25.0 % vermicompost application rate exhibited notable resistance to acid impact, and a greater amount of acid (up to 16 cm^3) caused only a slight pH change (up to 1.14 and 0.83 pH units respectively). When considering the data in Table (5), it can be seen that there is an inverse relationship between the curve slope and the soil resistance to change in pH, where the decrease in slope value means increasing soil resistance. The data show that, the highest soil resistance (lowest slope) was in 25.0 % VAR, it was 0.16 and -0.05 ter adding an alkali and acid solution respectively. While the lowest soil resistance (highest slope) was recorded in the control treatment (0.31 and -0.10 after adding NaOH and HCl respectively). The high resistance of these treatments may be due to the high organic carbon content and the presence of carbonates in vermicompost which act as a special "sink" for acid protons. Moreover, the addition of vermicompost led to increased soil resistance to change in pH by increasing the total surface available for cation exchange sites (Cox et al., 2001). Similar curve slopes were reported by Raczuk (2001) and Diatta (2006).

Table 2. An average of some physical soil properties as affected by different application rates of vermicompost

VAR [%]	WHC [%]	DBD [g cm^{-3}]	DPD [g cm^{-3}]	TP [%]
0.0	30.83 c	1.33 a	2.39 a	44.29 c
3.0	32.70 c	1.31 a	2.36 a	44.34 c
12.5	58.22 b	1.18 b	2.28 b	48.17 b
25.0	72.60 a	1.04 c	2.19 c	52.59 a
$LSD_{0.05}$	2.91	0.04	0.04	2.54

Mean of the same category followed by different letters are significantly different at 0.05 level of probability
VAR = Vermicompost application rates

Table 3. An average of some chemical soil properties as affected by different application rates of vermicompost (VAR)

Properties	Unit	VAR [%]				$LSD_{0.05}$
		0.0	3.0	12.5	25.0	
EC	[dS m^{-1}]	0.23 d	0.35 c	0.66 b	0.83 a	0.09
pH	-	4.5 c	5.22 b	7.39 a	7.61 a	0.38
TOC	[%]	1.33 c	1.44 c	2.17 b	3.15 a	0.57
OM	[%]	2.78 c	2.87 c	4.27 b	6.97 a	0.54
TN	[g kg^{-1}]	0.39 d	0.52 c	1.12 b	2.13 a	0.07
TC		12.20 c	12.97 c	24.37 b	39.47 a	2.18
C/N ratio	-	31.28 d	24.94 c	21.76 b	18.53 a	1.29
TS	[%]	0.21 c	0.22 c	0.27 b	0.31 a	0.03

Mean of the same category followed by different letters are significantly different at 0.05 level of probability

Table 4. The average values of cation exchange capacity, total exchangeable acidity and saturation percentage in soil with different application rates of vermicompost (VAR)

properties		Unit	VAR [%]				$LSD_{0.05}$
			0.0	3.0	12.5	25.0	
EB	Ca^{++}	cmol kg^{-1}	0.73 d	1.08 c	3.85 b	5.90 a	0.19
	Mg^{++}		0.69 d	0.89 c	1.17 b	2.06 a	0.08
	K^+		0.62 c	0.68 c	0.97 b	1.44 a	0.09
	Na^+		0.59 c	0.62 c	0.91 b	1.42 a	0.07
TEB			2.64 d	3.27 c	6.90 b	10.81 a	0.29
TEA			0.52 a	0.36 b	0.28 c	0.20 d	0.05
ECEC			3.16 d	3.63 c	7.18 b	11.01 a	0.19
PCEC			3.43 d	4.66 c	10.34 b	14.37 a	0.20
BS		%	83.55 d	90.08 c	96.10 b	98.18 a	0.21

Mean of the same category followed by different letters are significantly different at 0.05 level of probability

3.5. Effect of vermicompost on available soil macro and micro nutrients

The data in Table (6) shows the available element content (mg kg^{-1}) of the experimental soils as affected by different application rates of vermicompost. These data reveal that, available N, K, Ca and Mn increased significantly with different application rates of vermicompost as compared with the control. The increase was significant for P, Cu and Zn at addition rates of 12.5 and 25 % of vermicompost and insignificant at a rate of 3.0 %. These effects may have been caused by the high content of these elements in the vermicompost (Table, 1). Moreover, the available nutrient status of soil was greatly enhanced by the application of vermicompost (Prabha et al., 2007). Vermicompost increased the pH which effects nutrient availability (most elements prefer the neutral pH). In contrast, iron (Fe) was recorded in higher concentrations in the control than in other treatments. These results may be due to the fact that Fe is mobile under acid conditions, and by raising the pH with vermicompost its bioavailability is reduced (Im-Erb et al., 2004).

Table 5. The slope value by using acid and alkali solution of soil as affected by different additions of vermicompost

VAR[1] [%]	ACS[2] HCl	BCS[3] NaOH
0.0	-0.10	0.31
3.0	-0.10	0.29
12.5	-0.07	0.17
25.0	-0.05	0.16

1= vermicompost application rate, 2 = acid curve slope, 3 = base curve slope

Table 6. Average value of available macro-micro-nutrients content (mg kg^{-1}) in soil as affected by different application rates of vermicompost (VAR)

VAR [%]	Macronutrients					Micronutrients			
	KCl-N	Bray[1]-P	K	Ca	Mg	Fe	Cu	Zn	Mn
	[mg kg^{-1}]		EDTA-[mg kg^{-1}]			EDTA-[mg kg^{-1}]			
0.0	14.05 d	7.32 c	186.84 d	315.46 d	255.52 c	724.43 a	0.49 c	0.84 c	1.05 d
3.0	97.66 c	8.11 c	215.20 c	362.50 c	264.37 c	703.11 a	0.52 c	1.40 c	4.58 c
12.5	394.69 b	11.61 b	274.12 b	630.86 b	322.56 b	553.53 b	0.82 b	3.31 b	23.43 b
25.0	753.25 a	16.35 a	387.15 a	820.73 a	394.60 a	477.17 c	1.28 a	7.03 a	44.51 a
$LSD_{0.05}$	24.85	0.83	10.96	22.73	9.46	29.65	0.05	0.64	1.25

Mean of the same category followed by different letters are significantly different at 0.05 level of probability

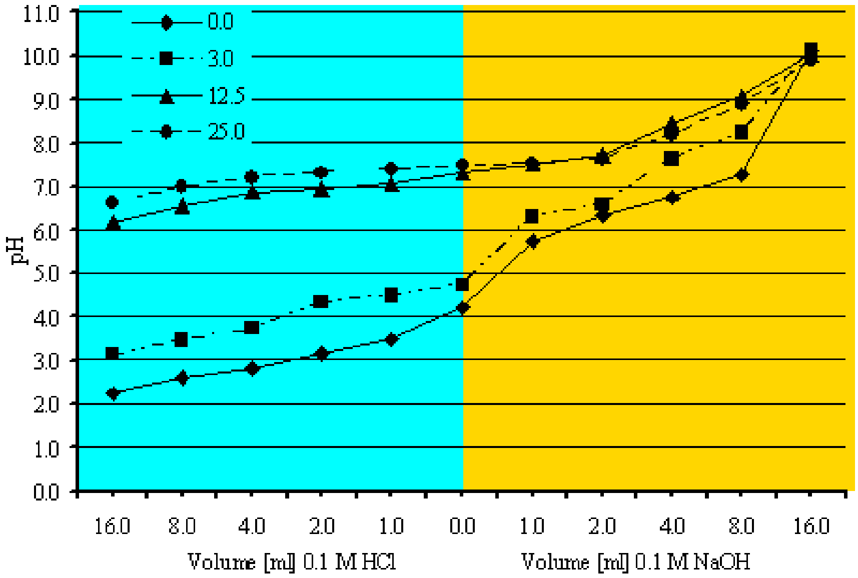

Figure 2. Effect of base (NaOH) and acid (HCl) additions on changes in buffering capacities of soil treated with vermicompost.

3.6. Effect of Vermicompost on Some Planting Properties

3.6.1. Chemical composition of grass (straw)

Diagnosis of the symptoms of nutrient deficiency in *RSM* grass grown in acid soil with application of various doses of wood vermicompost was confirmed by analysis of the complete straw (Table, 7). Analysis of the concentration of macro nutrients content (g kg^{-1}) in straw the leaves showed that nitrogen (N) was highly absorbed by the plants in treatments where vermicompost was added to the soil, showing significant differences from the control. According to Mengel and Kirkby (1987), NH_4-N uptake takes place most effectively in a neutral medium and decreases as the pH falls. Phosphorus (P) uptake were found not to significantly increase at a 3.0 % and 25.0 % vermicompost application rate when compared with control and 12.5 % rate respectively. K, Ca and Mg levels all showed a similar trend. Concentration of these nutrients increased significantly with the increase of vermicompost application rate when compared to the control (Renato et al., 2003). The data presented in Table 7 shows the straw micronutrient content (mg kg^{-1}). The data shows that, iron (Fe) uptake was increased significantly by increasing addition rate of vermicompost, with the highest concentration in the treatment of 25.0 % vermicompost (549.21 mg kg^{-1}).

Copper (Cu) levels were found not to differ among treatments, with slightly higher concentrations observed in treatment 25.0 % vermicompost (10.63 mg kg^{-1}). Zn concentration increased significantly in treatments 12.5, and 25.5 % vermicompost when compared to the control and 3.0 % vermicompost. Manganese (Mn) levels were found not to differ among vermicompost treatments but were higher than in the control treatment. In normal plants Mn concentration is usually between 40-120 mg kg^{-1} Mengel and Kirkby (1987). Normally the uptake of various plant nutrients depends upon pH, and nutrients are taken up at a higher rate in slightly acidic conditions. However, in some cases, ion competition, antagonism, or synergism among or between ions may occur, resulting in unusual uptake patterns. The absorption of cations is a more or less nonspecific process, depending mainly on the concentration of cation species in the nutrient medium (Mengel and Kirkby, 1987).

3.6.2. Fresh and dry matter yield

The results in Tables (8 and 9) and fig (3) show that, plants seem to respond positively to the application of wood vermicompost. Data in tables (8 and 9) show that, under different application rates of vermicompost, the fresh and dry weight (g pot^{-1}) for both straw and roots were increased significantly compared to the control. The application of 25.0 % vermicompost gave the highest yield of straw and roots, while the lowest value was recorded for the control treatment (Rasool et al., 2008).

Relative to fresh and dry weights in the control treatment, a high relative increase (RE, %) of fresh and dry weight for both straw and roots was recorded in the 25.0 followed by 12.5 and finally the 3.0 % vermicompost. For example, the increments of fresh straw weight due to the application of vermicompost were 325.14, 667.05 and 823.49 % for the 3.0, 12.5, and 25.0 % vermicompost treatments respectively. In contrast, the agronomic efficiency (AE) of fresh and dry weight for both straw and roots was higher in the 3.0 % vermicompost treatment than in other treatments compared to the control. When considering the mean values, each unit of vermicompost at an application rate 3.0 % had a greater efficiency of the yield compared to that of the other application rates. For example, at a 3.0 % dose of vermicompost each unit of vermicompost increased the fresh weight of straw by 1.98 units, while it was 0.98 units for each unit at a 12.5 % vermicompost application rate. From the previous discussion it can concluded that the higher availability of nutrients, especially N and P, and improved physical, chemical and biological soil properties (with the application of vermicompost) contributed to higher yields (More, 1994; Sailaja and Ushakumari, 2002).

4. CONCLUSION

Amelioration of post-mine raw materials with wood vermicompost resulted in improved soil physical properties, such as bulk density and total porosity. The utilized vermicompost had a positive impact on different soil chemical properties like CEC and pH which in turn affects the availability of macro and micro nutrients. An increase the addition rate of vermicompost led to increased soil resistance to change in pH. The soils treated with vermicompost had significant increases in grass biomass (fresh and dry matter yield) as well as enhanced plant uptake of macro-micro-nutrients.

Table 7. Average value of macro-micro-nutrients content of plants (straw) as affected by different application rates of vermicompost (VAR)

VAR [%]	Macronutrients					Micronutrients			
	N	P	K	Ca	Mg	Fe	Cu	Zn	Mn
	[g kg^{-1}]					[mg kg^{-1}]			
0.0	1.69 d	0.38 b	0.87 d	0.68 d	0.43 d	276.70 d	10.30 a	31.77 c	3.50 b
3.0	10.90 c	1.04 b	3.75 c	1.34 c	0.99 c	338.10 c	10.50 a	32.18 c	25.03 a
12.5	33.59 b	3.97 a	12.56 b	6.72 b	2.79 b	510.63 b	10.50 a	62.91 b	25.76 a
25.0	36.99 a	4.48 a	13.72 a	7.15 a	3.13 a	549.21 a	10.63 a	67.79 a	26.25 a
LSD$_{0.05}$	1.63	1.12	0.79	0.26	0.23	9.56	0.50	1.49	.45

Mean of the same category followed by different letters are significantly different at 0.05 level of probability

Table 8. Fresh weight (g/pot), relative increase (%) and its agronomic efficiency of both straw and roots of the plants as affected by different application rates of vermicompost

VAR^{1} (%)	Straw			Root		
	FMY^{2} [g pot^{-1}]	RI^{3} [%]	AE^{4}	FMY^{2} [g pot^{1}]	RI^{3} [%]	AE^{4}
0.0	1.83 d			0.65 d		
3.0	7.78 c	325.14	1.98	2.65 c	305.82	0.66
12.5	14.04 b	667.05	0.98	4.77 b	630.02	0.33
25.0	16.90 a	823.49	0.60	5.69 a	771.82	0.20
LSD $_{0.05}$	0.13			0.17		

1 = Vermicompost application rates, 2 = Fresh matter yield, 3 = relative increase, 4 = agronomic efficiency (see formula 1 and 2). Mean of the same category followed by different letters are significantly different at 0.05 level of probability

Table 9. Dry weight (g/pot), relative increase (%) and its agronomic efficiency of both straw and roots of the plants as affected by different application rates of vermicompost

VAR^{1} [%]	Straw			Root		
	DMY^{2} [g pot^{-1}]	RI^{3} [%]	AE^{4}	DMY^{2} [g pot^{-1}]	RI^{3} [%]	AE^{4}
0.0	0.19 d			0.07 d		
3.0	1.03 c	433.67	0.28	0.33 c	375.71	0.09
12.5	2.26 b	1072.53	0.17	0.90 b	1185.71	0.07
25.0	2.84 a	1371.5	0.11	1.29 a	1742.85	0.05
LSD $_{0.05}$	0.09			0.08		

1 = Vermicompost application rates, 2 = Dry matter yield, 3 = relative increase, 4 = agronomic efficiency (see formula 1 and 2). Mean of the same category followed by different letters are significantly different at 0.05 level of probability

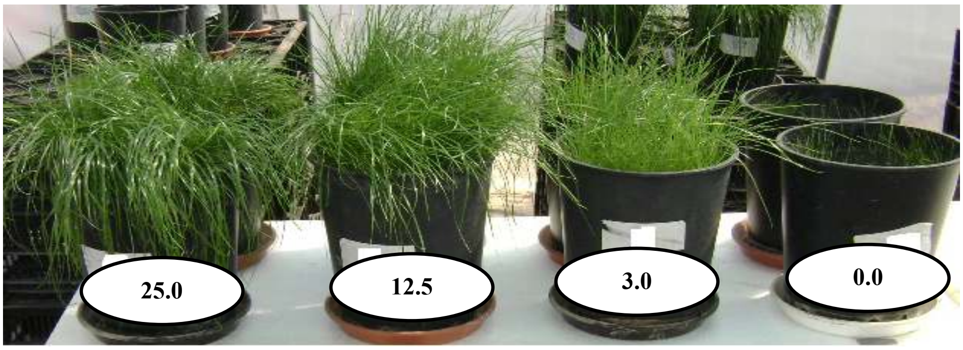

Figure 3. Effect of different application rate (%) of vermicompost on plant vitality and growth

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