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Evaluation of the influence of additives from different types of compost on the soil properties

Metodi Mladenov

University of Chemical Technology and Metallurgy, Department of Engineering Ecology, 1756 Sofia, Bulgaria
E-mail: mladenov@uctm.edu

Abstract

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The current study presents the results of the performed analyzes and the comparison of the effects of additives of different types of compost on the soil properties. Three different compost types were obtained using different methods of production - "home" composting method for the production of two of the composts was applied and the industrial composting installation from "tunnel" type for the third one was used. Also two different types of soil (*a* and *b*) with characteristics allowing a clear traceability of the changes in observed parameters of the prepared mixtures were used.

Various mixtures from three types (*aA, aB* and *bC)* with different ratio between the raw materials (composts and soils) were used. The mixtures were tested for the following parameters: active acidity (pH), conductivity, potential acidity (exchange and hydrolytic), relative and bulk density, porosity, cation-exchange capacity, carbon content, phosphorus (P_2O_5) – total and available. The obtained results for influence of composts on the soil properties are presented. It has been established that the most significant influence of the composts additives is on pH, porosity and carbon content. There are also direct ratio dependencies of changes of some of the indicators depending on the quantity of the compost used.

Keywords: amendments; compost; soil parameters; soil properties

Introduction

Composting is an aerobic process, the end result of which is the production of a useful product: compost, a natural soil improver, extremely rich in nutrients, the application of which in the soil systems leads to improvement of the basic soil characteristics and properties (Papafilippaki et al., 2015).

Compost is one of the means used to improve the structure and moisture capacity of the soil. Unlike other organic materials, compost derived from garden and agrarian organic materials has low or negligible concentrations of heavy metals and toxic organic compounds. The ratio of nitrogen, phosphorus and potassium in the compost is usually 1:1:1, which means that it is a source of moderate amounts of these three elements for the soils. (Chiumenti & Chiumenti, 2011)

The use of organic substances (including compost) results in significant beneficial effects for the soil: regenerates and restores poor and depleted soils, favors the development of the microorganisms leading to humus formation, suppresses the development of pathogens and pests, eliminates the need to use chemical fertilizers, and ultimately leads to increased yields (Chiumenti & Chiumenti, 2011**;** Khandaker et al., 2017).

The aim of the current work is to present the experimental results regarding the changes in the basic soil parameters at the addition of different types of composts to soils with low productivity.

Material and Methods

Raw material

As a raw material are used three types of composts (Table 1) and two different soils.

Table 1. Type of compost and characteristics

Parameter	Compost type		
	A	B	C
	Grass and hardwood residues	Grass and coniferous residues	Municipal wastes – mixture from food and park-wood wastes
	Composting method		
	"home" composting	"home" composting	industrial composting – "tunnel" type
Content of carbon, %	31.38	33.54	38.46
Content of phosphorus (P_2O_5), %	0.057	0.052	0.092
pH	5.78	5.19	7.29
Conductivity, mS/cm	1.53	5.73	2.19

The used type *a* soil is poor in organic matter, with low alkaline pH and low level of clay particles. The soil is low in phosphorus and has good porosity and moisture penetration. According to the literature (Broshtilova, 2001; Kartolev, 1960), this type of soil is characterized by their gray-green color (rarely reddish), has a poorly developed (up to 30 cm) humus horizon under which it is degraded, from the clay draw B horizon (subsoil, illuviated) – strongly thickened and loamy.

Type *b* soil is poor in organic matter with a yellowish to orange color, no humus horizon, with a strong acid reaction. The soil itself is an aggregate of excavated earth masses from an open mine for copper and zinc.

The established characteristics of the two soils define them as very suitable for the purpose of the study as they allow to clearly trace the changes in observed parameters of the prepared mixtures.

Experimental mixtures

In order to verify the possibility of improving the soil characteristics, different mixtures were prepared in different proportions of the soil and compost source components calculated for 1 kg. To prepare experimental mixtures with urban waste compost (alkaline), highly acidic soil (type *b*) is chosen, which is expected to lead to neutralization and low acid pH. To prepare experimental mixtures with compost from "home" composting (acidic) a slightly alkaline soil (type *a*) is chosen, which is expected to lead to neutralization and a slightly acidic pH.

The ratios used between the components for the various mixtures are shown in Table 2. The calculated quantities for the mixtures are weighed into a technical scale and mixed until homogenization.

Table 2. Components ratios in the mixtures

Mixture	Proportion (soil:compost)
aA1; aB1; bC1	1:0.5
aA2; aB2; bC2	1:1
aA3; aB3; bC3	1:1.5
aA4; aB4; bC4	1:2

Legend: *a, b* – soil type; *A, B, C* – type of compost; 1, 2, 3, 4 – number of the mixture

Parameters

The experimental mixtures were tested for the following parameters: active acidity (pH), conductivity, potential acidity (exchange and hydrolytic), relative and bulk density, porosity, cation-exchange capacity (CEC), carbon content, total and available phosphorus (as a form of P_2O_5). The studies were carried out both by standard techniques used in agrochemical practice and by appropriate adapted methods.

There were used standard methods for determination of conductivity and pH (BS EN 13038, 2011; BS EN 15933, 2012). For determination of the bulk density was applied standard method (BS EN ISO 17892-2, 2015). For determination of the exchange acidity and total phosphorus content, modification of standard method (BS ISO 11263, 2002; BS EN ISO 14254, 2018) with NaCl and HCL was used. Carbon content was determinate by the oxidimetric method of Thurin modified by Nikitin[1] (Mladenov, 2017).

The hydrolytic acidity and cation-exchange capacity were determinate by titrimetric chemical methods. Available phosphorus content was determinate by UV-VIS spectrophotometric method. For analysis of the physical property relative density the method described in (Mladenov, 2017) was used.

Results and Discussion

The results from the experiments on the pH, conductivity, cation-exchange capacity and potential acidity are given in Table 3. These for relative density, volume density and porosity are shown in Table 4. The values for carbon and phosphorus contents are shown in Table 5.

[1] This method gives vales about organic carbon. Because in the used soils wasn't established carbon, and compost is consist of organic matter, in the present article the admission was made that all carbon is organic.

Table 3. Results for active acidity, conductivity, CEC, and exchange and hydrolytic acidities

Sample	Parameters				
	pH (H_2O)	Conductivity (H_2O), mS/cm	CEC, cmol/kg	Exchange acidity, meq/100g soil	Hydrolytic acidity, meq/100g soil
Soil type *a*	7.8	0.10	12.6	0.53	0.67
aA1	7.8	0.66	20.9	0.53	3.08
aA2	7.5	1.15	23.5	0.79	4.49
aA3	7.3	1.54	17.4	1.09	4.80
aA4	7.1	1.23	20.3	1.30	6.04
aB1	7.4	5.62	48.2	0.53	1.21
aB2	7.3	5.41	45.1	0.79	1.54
aB3	7.1	6.09	44.6	1.26	2.01
aB4	7.0	6.17	41.5	1.31	2.58
Soil type *b*	4.7	0.71	11.2	13.51	20.36
bC1	5.3	0.48	44.1	1.56	7.84
bC2	6.3	0.54	48.6	2.60	7.77
bC3	6.4	1.21	49.3	3.64	6.25
bC4	6.8	1.61	49.6	4.94	5.01

Table 4. Results for relative and bulk density, and porosity

Sample	Parameter		
	Relative density	Bulk density, g/cm^3	Porosity, %
Soil type *a*	2.22	0.96	56.8
aA1	2.05	0.88	57.1
aA2	2.08	0.85	59.1
aA3	1.98	0.74	62.6
aA4	2.06	0.75	63.6
aB1	1.45	0.18	87.6
aB2	1.29	0.14	89.2
aB3	1.94	0.17	91.2
aB4	2.24	0.17	92.4
Soil type *b*	2.30	1.05	54.4
bC1	1.85	0.60	67.6
bC2	1.99	0.54	72.9
bC3	1.92	0.49	74.5
bC4	1.87	0.43	77.0

Table 5. Results for carbon content and phosphorus contents (P_2O_5) – total and available forms

Sample	Parameter		
	Carbon content, %*	P_2O_5-total, %	P_2O_5-available, %
Soil type *a*	0,09	0.014	0
aA1	5.0	0.030	0.004
aA2	6.2	0.034	0.007
aA3	11.2	0.039	0.009
aA4	11.6	0.044	0.011
aB1	2.6	0.016	0.002
aB2	6.8	0.017	0.004
aB3	8.7	0.020	0.004
aB4	8.9	0.021	0.005
Soil type *b*	0,05	0.304	0.047
bC1	4.7	0.351	0.066
bC2	5.7	0.387	0.073
bC3	6.6	0.432	0.080
bC4	8.4	0.462	0.085

When comparing mixtures of group *aA*, for active acidity (Table 3), the data show that the addition of compost as a whole results in lowering of the pH values of the mixtures and their determination in the neutral value at ratio soil:compost – 1:2 (Fig. 1). Similar values for this parameter were also obtained for mixtures of type *aB*, where pH change to neutral value was again observed at ratio soil:compost – 1:2 (Fig. 1).

For mixtures of type *bC* the data show that when the compost is added to the soil, the pH values rise and pass gradually to the weak acidic area, with the amounts added to the *bC4* mixture favoring the optimal pH for the development of the plants (Fig. 2).

For mixtures of type *aA* and *aB*, the obtained values for conductivity are higher than those for the used soils. By comparing the two groups of mixtures, it is found that the conductivity values are higher in *aB* type, which is an indication that type *B* compost is a carrier of a larger quantity of mobile ions of the elements.

For mixtures of type *bC*, unlike the previous two types, a relationship between the amount of input compost in the mixtures and the measured values is established. The specif-

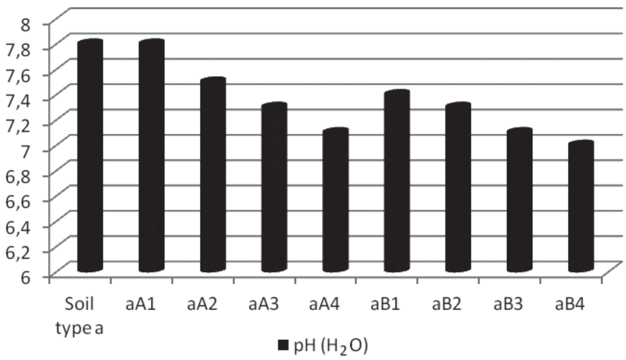

Fig. 1. Alteration of pH for mixtures types aA and a*B*

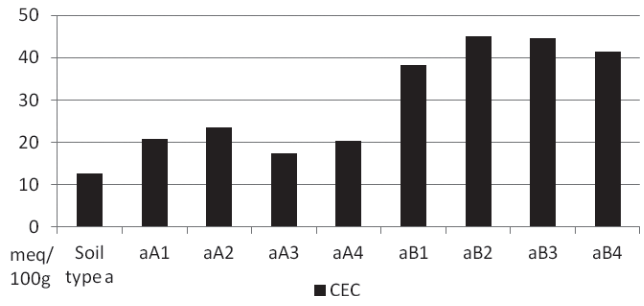

Fig. 3. Alteration of CEC for mixtures types aA and a*B*

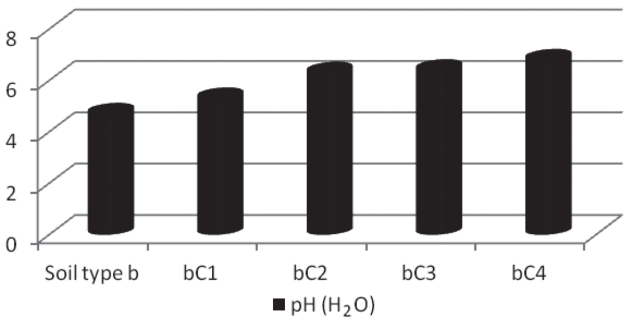

Fig. 2. Alteration of pH for mixtures type *bC*

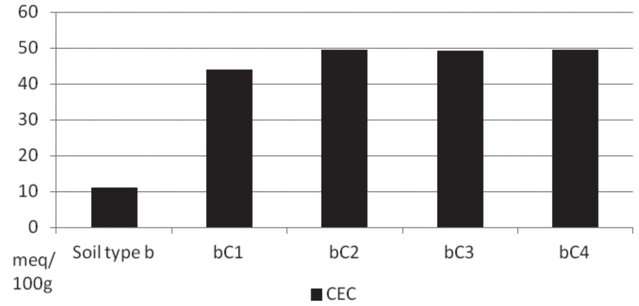

Fig. 4. Alteration of CEC for mixtures type *bC*

ics in this group of mixtures are that *bC1* and *bC2* have lower conductivity values than those of the used soil, whereas *bC3* and *bC4* are higher. These differences in values relative to the starting soil (*b*) are most likely due to ongoing blocking processes of the available moving ions in addition of compost in smaller quantities and reaching saturation, after which the larger compost additive results in enrichment with moving elements.

The results for the CEC parameter, for all three types of mixtures, show that the composts are carriers of basic cations (Ca^{2+}, Mg^{2+}, Na^{+} and K^{+}), and when added to the two soils lead to their enrichment – all values for the CEC in the experimental mixtures are higher than the values for the two soils (*a* and *b*). When comparing data between different mixtures, by type, it is evident that the amount of compost does not have a significant effect on this parameter. The data do not allow drawing a clear correlation between the amount of compost used and the values for the parameter (Fig. 3 and Fig. 4).

From the obtained results, it is found that the value for the exchange acidity is increased in the mixtures of types *aA* and *aB* by increasing the amount of the added compost. For *aA* type mixtures, this increase is minimal, whereas for *aB* there is a larger difference to the starting soil (*a*). For both types of mixtures, there is a direct relationship between the amount of compost deposited and the values for the indicator. For the four mixtures type *bC*, there is also a direct relationship between the amount of added compost and the values for this parameter. However, here the values obtained for the mixtures are below the soil type *b* values.

From the data presented in Table 3, it is evident that with an increase in the amount of compost in the experimental mixtures type *aA*, the values for the hydrolytic acid also increase and they are significantly higher than the value for the soil type *a*. There is a clear correlation. Similar is the trend for mixtures of type *aB*. On the basis of these data, it can be assumed that in the use of composts types *A* and *B*, it is possible to acidify the soil in case of unfavorable anthropogenic and natural impacts. For the *bC* type mixtures the obtained data show, that with the addition of more compost, hydrolytic acidity decreases, indicating that the compost generally leads to a decrease in acidity and blocking H^{+} and Al^{3+}.

Based on the results obtained, it was found that the four experimental mixtures *aA1-aA4* showed a decrease in the relative density in comparison with the used soil. The results obtained, although lower than the starting soil, are close to it. For mixtures of the groups *aB* and *bC*, the values for the relative density refer to similar trends as for type *aA*.

With the addition of compost it is expected that the organic particles introduced through it will reduce the bulk density. In line with this expectation, a decrease in density is observed in mixtures of *aA* type, relative to the used soil (*a*), but the values between the individual mixtures do not allow for a dependence on the amount added. For this parameter (Table 4), the resulting values for mixtures *aB1-aB4* lead to analogous interpretations like as type *aA* mixtures, but here the bulk density decreases significantly relative to the initial soil (type *a*). In the mixtures *bC*, (Table 4) it was found that with the addition of compost, the bulk density decreases twice in relation to the initial soil (*b*).

It is known that when increasing the bulk density of the soils decreases the porosity (respectively the water permeability). In the three mixtures *aA*, *aB* and *bC*, this dependence in general is confirmed, and in the mixtures of group *bC*, a clear trend is observed.

By the obtained results from the analysis of the four mixtures from the three types – *aA*, *aB* and *bC*, there is a clear tendency for the increase of the values of porosity, with the increase of the amount of added compost (Fig. 5 and Fig. 6). There is a direct relationship between the amount of the quantity of input compost and the values for the parameter, which is also expected, since the larger particles of compost would logically lead to increased porosity.

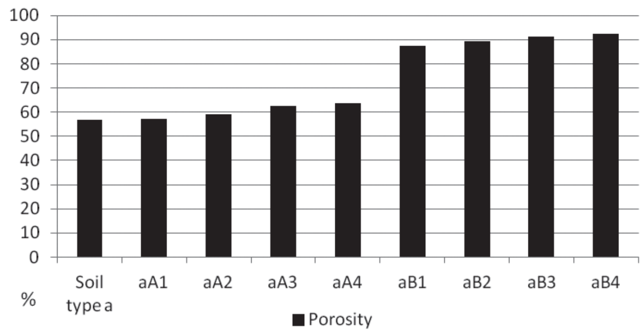

Fig. 5. Alteration of porosity for mixtures types aA and a*B*

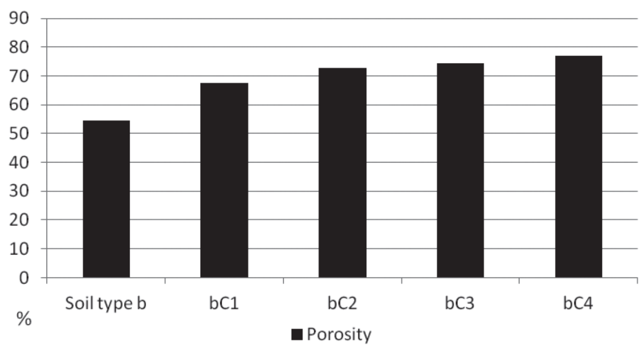

Fig. 6. Alteration of porosity for mixtures type *bC*

In the analysis of the initial soils *a* and *b* practically there wasn't found presence of carbon (Table 5) (the quantities of carbon are negligible – for soil *a* – 0.09% and for *b* – 0.05%).

Obtained results, show that there is a clear tendency to increase the carbon content by increasing the amount of compost added to the mixtures - the compost is expected to be a carbon carrier for the mixtures and this indicator has a direct proportional increase in the values depending on the quantity of the compost added (Table 5). This trend applies to all three types of mixtures *aA*, *aB* and *bC*. The highest values for the indicator are found in mixtures with the highest compost content of groups - *aA4*, *aB4* and *bC4*.

From the results obtained (for mixtures *aA1-aA4*), there is a clear tendency to increase the values for the two presented in Fig. 7 parameters – total and available forms of phosphorus. The analysis of the raw material (soil type *a*) reveals the presence of only total forms of phosphorus. The lowest values for the total and available forms of phosphorus are expected to be observed in the mixture *aA1* and the highest in the mixture *aA4*. For both parameters, there is a direct proportional increase in dependence of the amount of added compost, which is a sure sign that the used compost is a phosphorus carrier and will lead to soil enrichment with this element. A similar trend is observed for mixtures of type *aB*, and for this type of mixtures, it is significant that for the indicator phosphorus (total and available forms) no significant changes were found between the contents in the different mixtures of the series, in the mixtures obtained in relation to the pure soil – in values of the order of 0.01 for the total phosphorus and of 0.001 for the available forms are negligible.

For mixtures type *bC* the results are similar to those of the previous two types. What stands out here is that soil type *b* has a phosphorus content higher than that in soil type *a*, and it also found available forms of phosphorus (Table 5). In this type

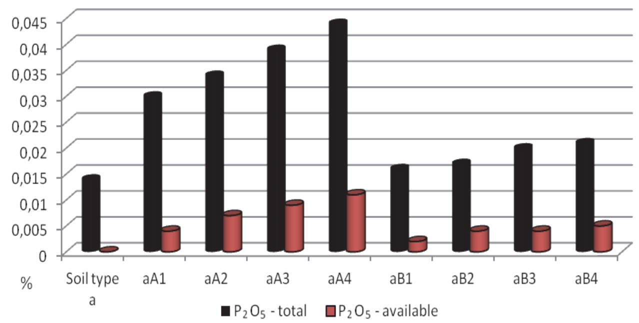

Fig. 7. Alteration of phosphorus contents for mixtures types aA and a*B*

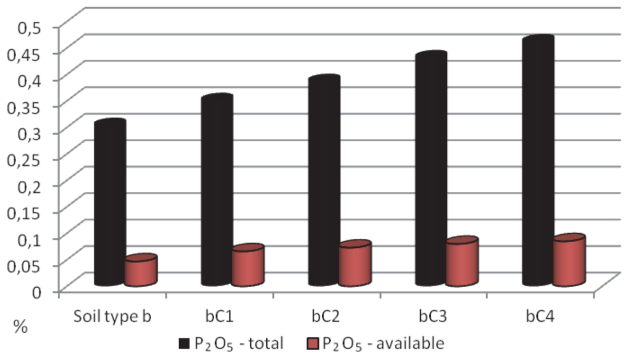

Fig. 8. Alteration of phosphorus contents for mixtures type *bC*

of mixtures both proportions of increase in the values with increase of the quantities of the added compost are observed, with the increase in the concentrations significantly higher compared to the previous two types of mixtures (Fig. 8).

Conclusions

It was found that the values for the exchange acidity increase with an increase in the amount of added compost in the mixtures of the three groups. However, the values for all mixtures are lower than those of the two used soils *a* and *b*.

In the hydrolytic acidity parameter, two direct proportional variations depend on the amount of compost incorporated. For mixtures of groups *aA* and *aB* the values for the parameter increase while for those of type *bC* they decrease.

For mixtures of type *aA* and *aB*, conductivity values were found higher than those for the used soils. For mixtures *bC*, two of the mixtures (*bC1* and *bC2*) have conductivity values lower than those of the soil *b*, while the other two (*bC3* and *bC4*) are higher. The obtained values do not allow generalization of the trend to change in depending on the amount of added compost.

As a result of the experiments carried out, it was found that the addition of compost to the soil generally led to an increase of the values of the cation-exchange capacity in the three types of experimental mixtures. It was found that compost is the main carrier of basic cations here.

The results show that composts *A*, *B* and *C* have a major influence on porosity. Adding them to the initial soils leads to pH neutralization (in soil type *a* from alkaline reaction to neutral, in soil type b from acid reaction to neutral) and carbon enrichment. For these three parameters, direct proportions were determined depending on the amount of compost added, with the best results being obtained in mixtures with ratio soil:compost – 1:2.

In the three types of mixtures a decrease of the relative and bulk densities in comparison with initial soils *a* and *b* was observed. The values obtained for the different mixtures within each type do not allow to summarize a trend in the variation of the parameters depending on the amount of added compost.

The data for the total and available forms of phosphorus show a direct proportional increase in the values in dependence of the added compost quantities for all three types of mixtures, which is a sure sign that the compost types (*A*, *B* and *C*) used will lead to the enrichment of treated soils with this element.

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