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EFFECT OF SEWAGE SLUDGE COMPOST TREATMENT ON CROP YIELD

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ABSTRACT

Due to the increasing number of sewage cleaning plants, the amount of sewage sludge also increases. We have to solve the environmentally sound disposal of the sludge. Results of many experiments show that sewage sludge and sewage sludge compost can be recycled as nutrient suppling material in agriculture. Municipal sewage sludge compost could cause the occurrence and accumulation of toxic elements in the soil. A small-plot experiment with sewage sludge compost was established in the spring of 2003. The applied compost contains 40% sewage sludge, 25% straw, 30% rhyolite, 5% betonite. The small-plot experiment was re-treated in the autumn of 2006, 2009, 2012and 2015. There are 4 treatments in five blocks, where the sewage sludge compost was applied at a rate of 0, 9, 18 and 27 tha^{-1} and then ploughed into the soil. Triticale as autumn cereal, maize and green pea as spring crops were sown in crop rotation every year. Plant samples were collected before harvesting. In this paper the results of crop yield between 2010-2012 are presented. Crops of triticale and maize were higher in the treated plots than in control one in 2010 and 2011. Treatment effect was not observed on green pea yield.The results show that the effect of applied compost doses depends on plant species and time. Our aim is to maintain this unique long-term experiment for studying the composted sewage sludge as a nutrient and organic matter source, applying it similarly to the farmyard manure.

Keywords: *sewage sludge, long-term experiment, crop yield, compost treatment.*

INTRODUCTION

The uses of sewage sludge include industrial utilization, landfill, combustion and composting for yield utilization (Sánchez et al. 2004). Composting is one of the most efficient waste treatment technologies to handling waste and enables to recycling of organic matter, reduce the amount of biodegradable organic matters

(Epstein, 1997; Stamatelatou et al., 2011; Amir et al., 2005; Ramirez et al., 2008; Marttinen et al., 2004; Oleszczuk, 2007; Poulsen and Berster 2010). Sandy soils, that are poor in mineral and organic colloids, have low fertility as determined by low water retention and a shortage of macro-and micronutrients. Good agricultural practices involve frequent applications of organic fertilizers, both conventional such as manure or plant residues, as well as non-conventional, such as peat, brown coal, sewage sludge or different kinds of composts (Chandra etal., 2009). Several years of sludge usage experiments demonstrate the effect of sewage sludge fertilizer. The plants responded favourable to the sludge treatment. Beneficial effects of sludge on soil are the increase of organic matter content, improvement of soil fertility, increase of nutrient content and microbiological activity and its ability for working as a complex fertilizer. The negative effects of the continuous application of composted sewage sludge can be the appearance of toxic elements, and in case of long-term usage the accumulation of the toxic elements in the soil and in the food chain (Vermes, 1998). Many countries introduce compost standards for regulating product quality including maximum-minimum trace elements or pollutant elements concentrations (Madrid, 2010).

Our more than 10 years old experiment is suitable to study the soil-plant system and to decide whether these elements are accumulated or not in this experimental condition which are similar to a general field application. The main objective was to observe the effect of composted sewage sludge on test plants. We analysed the relationship between the crop yield of test plants and some soil chemical properties.

MATERIALS AND METHODS

The experimental design is randomized block in five repetitions. Soil type is acidic sand(sand: 86.01%, silt: 4.08%, clay: 9.64%) at the Research Institute of Nyíregyháza,University of Debrecen, in the NE part of Hungary (GPS coordinates: 47º96' North, 21º72' East). Plot size is 12 x 18 m. Test plants are maize (*Zea mays* L.'MV NK 333'), triticale (*x Triticosecale Wittmack* 'Titán') and green pea (*Pisum sativum* L. 'Zita'). Plant samples were collected before harvesting. Green pea and triticale samples were collected from 4x1 square metres while maize samples were collected from 4x1 m rows. Crop yields were calculated from these samples.

The composted sewage sludge contained 40 m/m% dry matter(DM) of sewage sludge, 25 m/m% DM of rye straw, 30 m/m% DM of rhyolite and 5 m/m% DM of bentonite and was applied to the 0-30 cm soil layer in every 3rd year at the rate of 0, 9, 18 and 27 t ha^{-1} after harvesting in 2003, 2006, 2009, 2012 and 2015. Table 1 contains the important parameters of the applied compost which has more than 25 m/m% DM organic matter content therefore it is good for improving the organic matter content of soil. The addition of composted sewage sludge improves some physical and chemical properties of sandy soil. The pH(H_2O) of compost was near 7, thereby we can increase the pH of acid soil with application of compost. The nitrogen (N), phosphorus (P) and potassium (K) content of composted sewage sludge can enhance the available nutrients content of soil. The toxic elements content of compost was under the Hungarian limit values.

Table 1. Main characteristics of the applied compost

Parameter	Average	
pH (H_2O 1:10)		6.5-8.5
Dry matter content [m/m% row matter]	at least	50
Organic matter content [m/m % dry matter]	at least	25
Water soluble total salt [m/m% dry matter]	at least	4
Total N-content [m/m% dry matter]	at least	1
Total P_2O_5-content [m/m% dry matter]	at least	0,5
Total K_2O-content [m/m% dry matter]	at least	0,5
As (mg kg^{-1})	maximum	10
Cd (mg kg^{-1})	maximum	2
Co (mg kg^{-1})	maximum	50
Cr (mg kg^{-1})	maximum	100
Cu (mg kg^{-1})	maximum	100
Hg (mg kg^{-1})	maximum	1
Ni (mg kg^{-1})]	maximum	50
Pb (mg kg^{-1})	maximum	100
Se (mg kg^{-1})	maximum	5

Statistical analysis was done by SPSS 22.0 statistical program. Treatment effect was evaluated for each year separately by one-way ANOVA followed by Tukey's test ($p<0.05$). Pearson correlations were applied to determine the relationships between crop yield of test plant and soil chemical properties.

RESULTS AND DISCUSSION

We observed the stronger green colour and healthier crops of triticale in the treated fields. The yields of treated plants were higher than the control ones (Table 2.) in three years (2010-2012). These data show that the favourable beginning developmental conditions couldresult in the increase of the crop yield. We found significant differences among the treatments. The highest crop yield was caused by the 27 t ha^{-1} dose of compost in 2010. The combination with fertilizers application, which is used insewage sludge compost, had the most effect on crop yield of cereal crops (Jalilian, 2015).

Table 2.Crop yield of triticale in the sewage sludge compost experiment from 2010 to 2012

Dose of compost t ha^{-1}	Crop yield of triticale t ha^{-1}		
	2010	2011	2012
Control	1.3 a	1.9 a	1.8 a
9	1.6 ab	2.4 ab	2.3 ab
18	1.6 ab	2.8 b	2.7 b
27	1.8 b	3.0 b	2.9 b

There were significant differences between treatments, according to the Tukey's test (p<0.05). Therefore we signed the "a, b" index in the table.

In 2011 and 2012 the 18 and 27 t ha^{-1} treatments resulted in the highest plant products of triticale (in 2011: 2.8 and 3.0 t ha^{-1}, in 2012: 2.7 and 2.9 t ha^{-1}). The use of complex fertilizers made from artificial fertilizers and organic manure can improve soil biological activity and chemical, physical properties of soil (Berecz et al., 2005). The improved soil condition increases the yield of cultivated plants. The changes of maize yield after treatments were similar to crop yield of triticale (Table 3.). In 2010 9.0 and 9.5 t ha^{-1}crop yields were measured in 18 and 27 t ha^{-1} treated plots and similar results were obtained in 2011. These results indicated the favourable effects of sewage sludge compost on maize as a nutrient source. Delgado et al. (2002) also treated this plant with sewage sludge compost without observing any toxic effects. Moreover, lower zinc (Zn) and nickel (Ni) concentrations were measured in treated than in non-treated plants in their experiment.

Table 3.Crop yield of maize in the sewage sludge compost experiment from 2010 to 2012

Dose of compost t ha^{-1}	Crop yield of maize t ha^{-1}		
	2010	2011	2012
Control	6.3 a	5.5 a	4.8 a
9	7.4 ab	7.1 ab	4.6 a
18	9.0 b	8.2 b	5.1 a
27	9.5 b	8.4 b	4.9 a

There were significant differences between treatments, according to the Tukey's test (p<0.05). Therefore we signed the "a, b" index in the table.

In case of green pea the treatments effects were favourable in 2010 (Table 4.). In the other years the treatment was not caused any increase of the crop yield, moreover,in 2012 It was a higher crop yield washarvested in all treatments.

Table 4.Crop yield of green pea in the sewage sludge experiment in from 2010 to 2012

Dose of compost t ha^{-1}	Crop yield of green pea t ha^{-1}		
	2010	2011	2012
Control	1.3 a	1.0 a	2.9 a
9	1.7 b	1.1 a	3.2 a
18	1.8 b	1.0 a	3.3 a
27	1.6 b	0.8 a	3.1 a

There were significant differences between treatments, according to the Tukey's test ($p<0.05$). Therefore we signed the "a, b" index in the table.

The measured data did not show typical results of crop production of green pea because weather conditions were unfavourable in 2010-2011. The highest recorded mean value (3.3 t ha^{-1}) was resulted by the treatment 18 t ha^{-1} in 2012.Farmers have been recognized that adopting N-efficient management strategies can significantly affect the growth, development and crop yield of many plant species (Binder et al., 2000; Hirel et al., 2007). The lowest recorded mean value (0.8 t ha^{-1}) was measured in the treatment of 27 t ha^{-1} in 2011.

Table 5. Correlation between crop yield of test plants and soil chemical properties in 2010

	Treatments		pH (KCl)	pH (H_2O)	P_2O_5 mg kg^{-1}	K_2O mg kg^{-1}	Na mg kg^{-1}	Mg mg kg^{-1}
Crop yield of triticale t /ha^{-1}	Control	Pearson Correlation	n.s.	n.s.	n.s	n.s.	-0.551*	n.s.
	9 t ha^{-1}		n.s.	n.s.	n.s	n.s.	n.s.	n.s.
	18 t ha^{-1}		n.s.	n.s.	0.607*	n.s.	n.s.	n.s.
	27 t ha^{-1}		n.s.	n.s.	n.s	n.s.	n.s.	n.s.
Crop yield of maize t /ha^{-1}	Control	Pearson Correlation	n.s.	n.s.	n.s	n.s.	n.s.	n.s.
	9 t ha^{-1}		-0.649**	-0.647**	-0.586*	n.s.	n.s.	0.584*
	18 t ha^{-1}		-0.729**	-0.730**	n.s	0.618*	0.702**	0.603*
	27 t ha^{-1}		-0.641**	-0.659**	n.s	n.s.	0.601*	0.718*
Crop yield of green pea t /ha^{-1}	Control	Pearson Correlation	n.s.	n.s.	n.s	n.s.	n.s.	n.s.
	9 t ha^{-1}		n.s.	n.s.	n.s	n.s.	n.s.	n.s.
	18 t ha^{-1}		-0.557*	-0.547*	n.s	n.s.	n.s.	n.s.
	27 t ha^{-1}		n.s.	n.s.	n.s	n.s.	n.s.	n.s.

n.s. non-significant differences
**Correlation is significant at the 0.05 level (2-tailed).*
***Correlation is significant at the 0.01 level (2-tailed).*

In this year we observed negative correlation in all treatments among the soil pH and the yield of maize. Although, the maize grows on a wide range of soil types in the pH range of 5 – 8, but best growth is achieved in the range of pH 5.6 - 7.5 (Bocz, 1992). In the experiment the pH was between 4.5 - 6.8. We got strong positive correlations for Mg content in the crop yield of maize. As well as we studied the correlation between crop yield of test plants and soil chemical properties in 2012 (Table 6.). In the 3rd year (2012) after compost application (2009) we did not observe correlation between crop yield of triticale and soil chemical properties.

Table 6.Correlation between crop yield of test plants and soil chemical properties in 2012

	Treatments		pH (KCl)	pH (H_2O)	P_2O_5 mg kg^{-1}	K_2O mg kg^{-1}	Na mg kg^{-1}	Mg mg kg^{-1}
Crop yield of triticale t /ha^{-1}	Control	Pearson Correlation	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	9 t ha^{-1}		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	18 t ha^{-1}		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	27 t ha^{-1}		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Crop yield of maize t /ha^{-1}	Control	Pearson Correlation	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	9 t ha^{-1}		n.s.	n.s.	-0.684**	n.s.	n.s.	n.s.
	18 t ha^{-1}		-0.710**	-0.653**	n.s.	n.s.	n.s.	n.s.
	27 t ha^{-1}		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Crop yield of green pea t /ha^{-1}	Control	Pearson Correlation	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	9 t ha^{-1}		n.s.	n.s.	0.593*	-0.528*	-0.781**	-0.570*
	18 t ha^{-1}		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	27 t ha^{-1}		n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

n.s. non-significant differences
**Correlation is significant at the 0.05 level (2-tailed).*
***Correlation is significant at the 0.01 level (2-tailed).*

Similar to the results of 2010, we observed negative correlation among the pH(KCl) and pH(H_2O), and the yield of maize but only in 18 t ha^{-1} compost treated plot. The pH has strong effect on the availability of P for plants (Bakker et al., 2005) which is proved by our results, too. Moreover, the water content of soil has strong effect on the nutrient availability. The year of 2010 was extra humid in Hungary, the yearly precipitation was 995 mm (the average is 550-600 mm in our region), while the year of 2012 was dry with 382 mm precipitation. Dry soil conditions decrease the nutrient availability (Binkley and Vitousek, 1989).

CONCLUSION

This study confirmed that the composted sewage sludge can be successfully used in the production of triticale (*x Triticosecale Wittmack*'Titán') and maize (*Zea mays* L.'MV NK 333') because the increase in the average value of crop yield of these test plants were proved. However, any treatment effects on green pea yield were not found.The results show that the effect of applied compost doses depends on plant species, the elapsed time after compost treatment and the actual climate of the vegetation period.Crops of triticale and maize were higher in the treated plots than in control one in 2010 and 2011.In our experiments we have found, that the composted sewage sludge could be used efficiently in crop production but more studies needed to screening the reactions of other plant species by planning more effective crop rotations based on this plant nutrient supplying method.

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REFERENCES

Amir S., Hafidi M., Merlina G., Hamdi H., Jouraiphy A., El Gharous M., Revel J.C. (2005). Fate of phthalic acid esters during composting of both lagooning and activated sludge.Process Biochem. 40. 2148-2190.

Bakker C., Rodenburg J., and Bodegon van P. M. (2005). Effect of Ca- and Fe-rich seepage on P availability and plant performance in calcareous dune soils.Plant and Soil. 275. 111-122.

Berecz K., Kismanyoky T. and Debreczeni K. (2005).Effect of organic matter recycling in long-term fertilization trials and model pot experiments.Communications in Soil Science and Plant Analysis. 36 (1-3). 191-202.

Binder D. I., Sander D. H., Walters D. T. (2000). Maize response to time of nitrogen application as affected by level of nitrogen deficiency.Agron. J. 92. 1228-1236.

Binkley D. and Vitousek P. (1989).Soil nutrient availability. Plant Physiological Ecology. 75-96.

Bocz E. (Ed.) (1992).Field crop production (In Hungarian). Mezőgazda Kiadó, Budapest.

Chandra R., Bharagava R.N., Yadav S., Mohan D. (2009). Accumulation and distribution of toxic metals in wheat (*Triticum aestivum* L.) and Indian mustard (*Brassica campestris* L.) irrigated with distillery and tannery effluents. Journal of Hazardous Materials 162.1514–1521.

Delgado A., Porcel C., Miralles De I. H., Beltrán R., Beringola B., Martín S. (2002).Sewage sludge compost fertilizer effect on maize yield and soil heavy metal concentration. Rev. Int. Contam. Ambient. 18 (3) 147-150.

Hirel B., Le Gouis J., Ney B., Gallais A. (2007). The challenge of improving nitrogen use efficiency in crop plants: towards a more central role for genetic variability and quantitative genetics within integrated approaches. J. Exp. Bot. 58. 2369-2387.

Jalilian J. (2015). The effect of farm slope and application of different fertilizer sources on wheat on wheat yield. Sixth International Scientific Agricultural Symposium “Agrosym 2015”. Bosnia and Herzegovina, Jahorina, 15-18 October 2015. Book of proceedings 209-213.10.7251/AGSY1505209J.

Epstein E. (1997). The science of composting.CRC Press Pensilvania USA.

Madrid L. (2010). “Heavy metals”: reminding a long-standing and sometimes forgotten controversy. Geoderma 155.128-129.
Marttinen S., Hanninen K., Rintala J. 2004. Removal of DEHP in composting and aeration of sewage sludge.Chemosphere 54.262-272.
Oleszczuk P. (2010). Toxicity of light soil fertilized by sewage sludge or compost in relation to PAH content.Water Air Soil Pollut. 210. 347-356.
Poulsen T.G., Berster K. (2010). Organic micro pollutant degradation in sewage sludge during composting under thermophilic conditions. Environ. Sci. Technol. 44. 5086-5091.
Ramírez W.A., Domene X., Ortíz O., Alcaniz J.M. (2008). Toxic effects of digested, composted and thermally-dried sewage sludge on three plants. Bioresource Technol. 99. 7168-7175.
Sánchez Monedero M.A., Mondini C.D., De Nobili M., Leita L., Roig A. (2004). Land application of biosolids: soil response to different stabilization degree or treated organic matter. Waste Manage. 24. 325-332.
Stamatelatou K., Pakou C., Lyberator G. (2011). Occurrence, toxicity, and biodegradation of selected emerging priority pollutants in municipal sewage sludge. In: Murray, M.-Y.(Ed.), Comprehensive Biotechnology, 473-484.
Várallyay Gy. (2002). Basics in soil science of agricultural water management (In Hungarian).Egyetemi jegyzet, Szent István Egyetem, Mezőgazdaság- és Környezettudományi Kara, Gödöllő. 128.
Vermes L. (1998).Waste management and waste utilization (In Hungarian). Mezőgazda Kiadó, Budapest.