Colloquium Biometricum 46
2016, 59−69

CHANGES OF CHOSEN PROPERTIES OF SANDY SOIL IN RESULT OF COMPOST APPLICATION

Małgorzata Graczyk[1], Monika Jakubus[2]

[1]Department of Mathematical and Statistical Methods
Poznań University of Life Sciences
Wojska Polskiego 28, 60-637 Poznań, Poland
[2]Department of Soil Science and Land Protection
Poznań University of Life Sciences
Szydłowska 50, 60-656 Poznań, Poland
e-mails: magra@up.poznan.pl; monja@up.poznan.pl

Summary

In this paper, the analysis of variance of the results of experiment conducted in laboratory conditions is described. The objective of this study was to evaluate changes in soil reaction, hydrolytic acidity, sum of bases and available potassium and magnesium in sandy soil incubated with two doses of composted sewage sludge (30 and 120 Mg per hectare) over period of 180 days. The data obtained showed that with regard to the unamended soil, both the 30 and 120 Mg per hectare treatments similarly influenced on analyzed properties but the effect was more visible at the case of the higher compost dose. Additionally it was found, that compost prepared on the basis of sewage sludge is an important source of potassium and magnesium. During incubation process the patterns of changes of hydrolytic acidity and available potassium and magnesium were different for particular treatments

Keywords and phrases: analysis of variance, compost, incubation, post-hoc analysis, soil properties

Classification AMS 2010: 6207, 62K10

1. Introduction

The decline of soil organic matter, as a consequence of intense soil cultivation practice, has been identified as one of the most important threats to soil quality. Moreover, Thematic Strategy for Soil Protection (2006) concerns essential problems related to soil degradation and among other things, the decline of organic matter was stressed as one of many factors causing soil degradation. To reverse these impacts, application of organic substances has been employed. Due to the high content of organic matter and nutrients in sewage sludge, land application or composting is commonly regarded as the most effective way of recycling this organic soil waste. Composting is a biological process of aerobic decomposition, which degrades labile organic matter to carbon dioxide, water vapour, ammonia, inorganic nutrients and a stable organic material (compost) containing humic-like substances. Composts are valuable sources of nutrients and organic matter, which is of significance in agricultural and horticultural production. There are many papers dealing with the benefits of composted sewage sludge on different soil properties: physical, chemical, physico-chemical and biological, see Bustamante et al. (2010), Duong et al. (2013), Jakubus (2013a), Weber et al. (2014), Rigby et al. (2016). Compost can be defined as the stabilized and sanitized product of composting, which has undergone decomposition and is in the process of humification. The biological decomposition of organic matter depends on the degradation rate of a wide range of C compounds present in the sample (carbohydrates, amino acids, fatty acids, lignin, etc.). According to this, mineralization of compost may undergo with different dynamic and in different way may influence on soil properties. Also, the applied doses of compost can play significant role in the decomposition process.

The effects of compost composition and its dose on the rate of compost decomposition and influence on soil physico-chemical properties are poorly understood. Therefore, an incubation experiment was conducted in this study to investigated the rate of decomposition of compost prepared on the basis of sewage sludge and applied at two doses into sandy soil. The changes of soil reaction, hydrolytic acidity, sum of bases and available magnesium and potassium were determined. In the experiment, the dynamic of pattern of quantity changes of particular soil properties was observed during the compost decomposition. The observations were carried out in individual, 12th terms, simultaneously for soil amended with compost (two doses TI and TII) and without such fertilization (T0). To analyze experimental data, ANOVA and analysis of regression were used.

2. Materials and methods

Soil used in this experiment was collected from the top layer (0-25 cm) of arable land. Sewage sludge compost was added to soil at doses of 0 (control soil, T0), 30 (TI) and 120 Mg (TII) of dry matter per hectare. Samples of 1 kg dried soil were weighed in triplicate and mixed with compost doses. Each mixture was wetted to 60 % field capacity and placed in 1L plastic boxes. Each treatment for particular term was managed at 1 replication. The samples were incubated at 25°C for 180 days. The individual replications of each experimental treatment were eliminated at 12 incubation dates (terms). The collected soil samples were dried and then subjected to analysis.

The following parameters of physico-chemical soil properties were determined: pH, hydrolytic acidity (Hh), sum of bases (SB) and amounts of available potassium and magnesium. The above properties were determined by methods commonly applied in soil science analyses; their detailed descriptions can be found in Jakubus (2013b).

For statistical analysis, we study the linear model without interaction

$$y_{ijk} = \mu_k + \alpha_{ik} + \tau_{jk} + \varepsilon_{ijk}, \tag{2.1}$$

where y_{ijk} is the content of k^{th} property in i^{th} compost and in j^{th} term, μ_k denotes the general mean for k^{th} property, α_{ik} is an effect of i^{th} compost dose and k^{th} property, τ_{jk} is an effect of k^{th} property in j^{th} term and and ε_{ijk} is random error of experimental factors with $\mathrm{E}(\varepsilon_{ijk}) = 0$ and $\mathrm{Var}(\varepsilon_{ijk}) = \sigma^2$, $i = 0, \mathrm{I}, \mathrm{II}$, $j = 1, 2, ..., 12$, $k \in \{\mathrm{pH}, \mathrm{Hh}, \mathrm{SB}, \mathrm{K}, \mathrm{Mg}\}$. Taking into consideration the fact that our studies directly did not connect to the rate of mineralization of compost in soil, only the effect of this process on soil properties was investigated, we assumed that analysis of interaction between compost doses and term of incubation will be invalid. Moreover, the obtained data although reliable in such scheme of experiment should be accidental and lead to the false conclusions.

According to the character of the experiment, we study each property separately. So, in order to check if experimental factors (soils and terms) influenced significantly on mean value of studied features, the null hypothesis concerned doses of compost $\mathrm{H}_0 : \alpha_{0k} = \alpha_{Ik} = \alpha_{IIk}$ against the alternative, at least one mean is distinct and null hypothesis concerned terms

$H_0 : \tau_{1k} = \tau_{2k} = \cdots = \tau_{12k}$, against the alternative at least one mean is distinct, should be verified, $k \in \{ \text{pH, Hh, SB, K, Mg} \}$.

The standard F test was used for verifying if there are significant differences of mean content of studied properties between composts as well as between terms. Providing with details, we considered independently five properties of soil and for each of them we performed analysis of variance, see for details Elandt (1964) and Platt (1978). In our study we take $\alpha = 0.05$. After analysis of variance, for further data analysis, we can see that there are significant differences among the groups. For each considered property, the Tukey HSD test can clarify which term among the sample in specific has significant differences. Moreover, based on this test, we check which compost dose among the sample in specific has significant differences. Finally, for detection the trends in changes in parameters of physic-chemical soil properties, we determine the regression coefficients. So, the linear model is of the form

$$y_{ik} = \beta_{0ik} + \beta_{1ik} x_{il} + \varepsilon_{ik}, \tag{2.2}$$

where β_{0ik}, β_{1ik} denote the regression coefficients, ε_{ik} is random error of experimental factors with $E(\varepsilon_{ik}) = 0$ and $\text{Var}(\varepsilon_{ik}) = \sigma^2$, $i = 0, \text{I}, \text{II}$, $k, l \in \{ \text{pH, Hh, SB, K, Mg} \}$.

3. Results and discussion

On the basis of obtained data, we can stated that the higher dose (120 Mg) of compost significantly influenced on the higher values of hydrolytic acidity, sum of bases and content of available magnesium and potassium (Fig. 1).

The addition of organic matter can either increase the soil pH (Giannakis et al.2014), decrease or do not produce changes of this parameter (Sciubba et al. 2014). In presented studies the compost application (TI and TII) didn't influence on soil reaction. We observe minor changes in values of pH (Fig. 1).

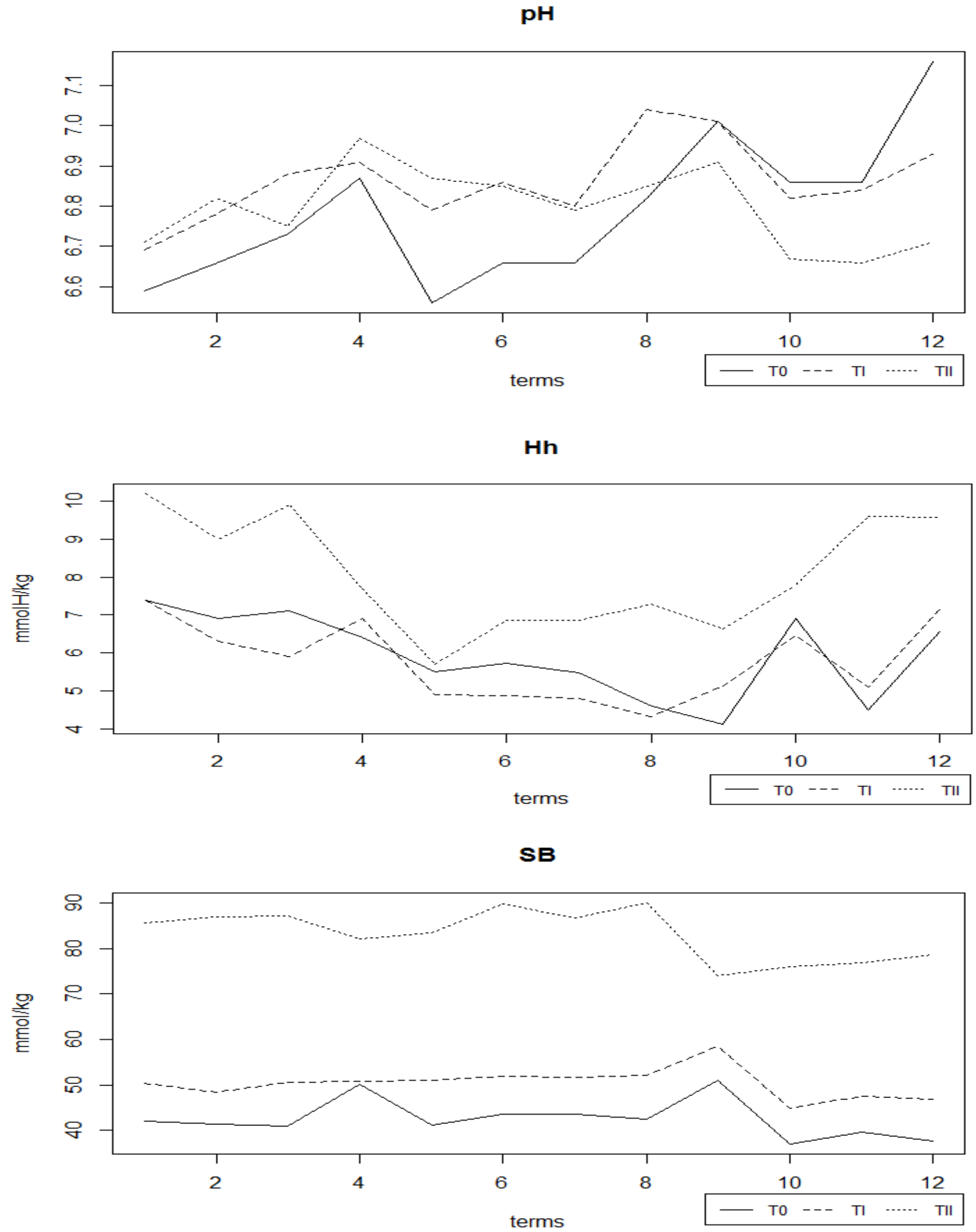

Fig. 1. The patterns of soil properties changes in dependence on treatment and term

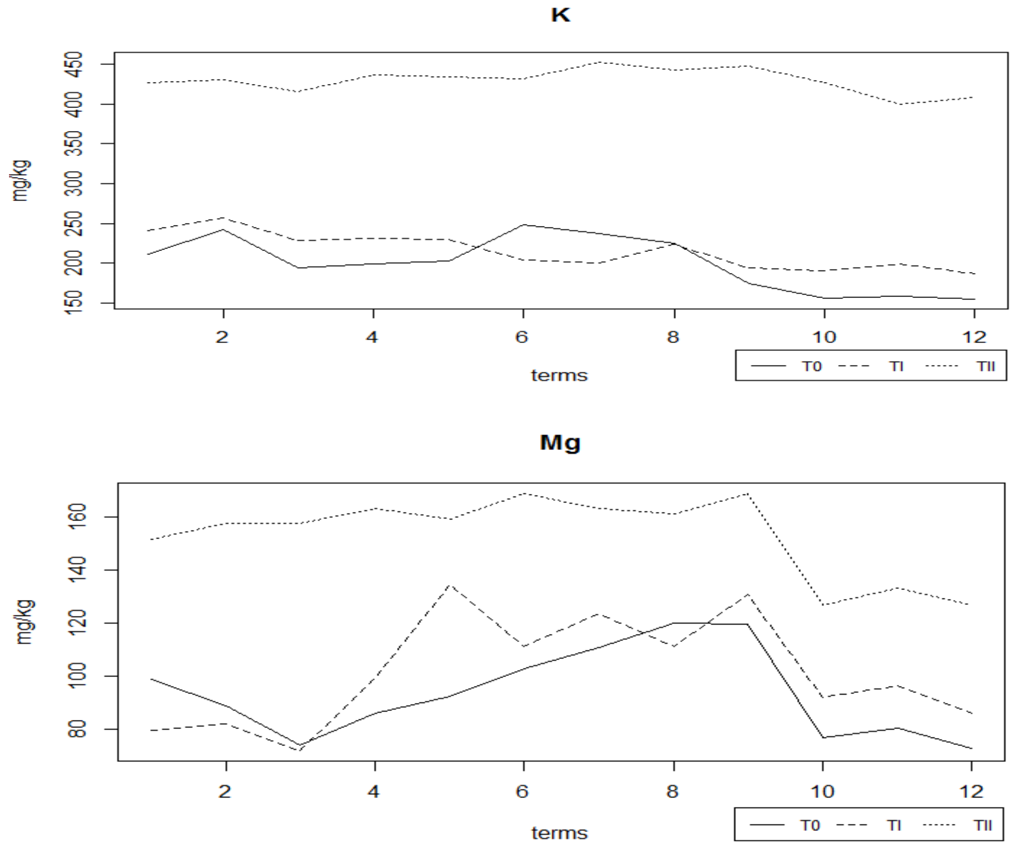

Fig. 1. cont. The patterns of soil properties changes in dependence on treatment and term

Average values of pH did not differ significantly under experimental factors for terms and doses of compost: T0, TI, TII (treatments), Tab. 1. Our results highlight also the importance of organic amendment at higher dose for maintenance the stabile level of SB. Despite of the SB values obtained for particular experiments treatment were not the same, Tab. 1 and 3, the discussed parameter for soils at the 1st and the last term of incubation presented the comparable values, Fig. 1.

Table 1. ANOVA results for studied properties

Source of variation	SS	df	MS	Test statistic	p-value
pH					
Term	0.294	11	0.027	2.250	0.057
Dose of compost	0.041	2	0.020	1.667	0.213
Error	0.270	22	0.012		
Hh					
Term	37.434	11	3.403	5.854	**0.000**
Dose of compost	40.470	2	20.235	34.808	**0.000**
Error	12.789	22	0.581		
SB					
Term	317.9	11	28.9	1.833	0.109
Dose of compost	11101.5	2	5550.7	352.018	**0.000**
Error	346.9	22	15.8		
K					
Term	12681	11	1153	3.058	**0.012**
Dose of compost	394713	2	197357	523.605	**0.000**
Error	8292	22	377		
Mg					
Term	7721.8	11	702.0	5.406	**0.000**
Dose of compost	25355.5	2	12677.8	97.630	**0.000**
Error	2856.8	22	129.9		

Table 2. p-value for Tukey test of multiple comparisons: terms

	Hh											
	11	10	9	8	7	6	5	4	3	2	1	
	0.58	0.99	**0.03**	**0.04**	0.10	0.14	**0.03**	0.98	1.00	1.00	1.00	12
		0.99	0.82	0.90	0.99	1.00	0.87	1.00	0.70	0.89	0.14	11
			0.24	0.31	0.60	0.71	0.29	1.00	1.00	1.00	0.65	10
2	0.99			1.00	1.00	1.00	1.00	0.27	**0.04**	0.84	**0.00**	9
3	1.00	0.73			1.00	1.00	1.00	0.36	0.06	0.12	**0.00**	8
4	1.00	0.96	1.00			1.00	1.00	0.65	0.15	0.28	**0.01**	7
5	1.00	0.96	1.00	1.00			1.00	0.75	0.20	0.37	**0.02**	6
6	1.00	1.00	1.00	1.00	1.00			0.32	**0.04**	0.11	**0.00**	5
7	1.00	1.00	0.99	1.00	1.00	1.00			1.00	1.00	0.60	4
8	1.00	1.00	0.99	1.00	1.00	1.00	1.00			1.00	0.98	3
9	0.97	0.44	1.00	0.99	0.99	0.95	0.91	0.90			0.92	2
10	0.54	0.10	0.95	0.71	0.70	0.49	0.41	0.39	1.00			
11	0.36	**0.04**	0.85	0.51	0.50	0.31	0.25	0.24	0.98	1.00		
12	0.27	**0.03**	0.76	0.41	0.40	0.23	0.19	0.18	0.95	1.00	1.00	
	1	2	3	4	5	6	7	8	9	10	11	
	K											

Table 2. cont.

Mg											
11	10	9	8	7	6	5	4	3	2	1	
1.00	1.00	**0.00**	**0.03**	**0.02**	0.07	0.05	0.53	1.00	0.91	0.89	12
	1.00	**0.03**	0.19	0.13	0.33	0.27	0.96	1.00	1.00	1.00	11
		0.01	0.07	**0.04**	0.13	0.11	0.75	1.00	0.98	0.98	10
			1.00	1.00	0.97	0.98	0.35	**0.02**	0.11	0.12	9
				1.00	1.00	1.00	0.89	0.12	0.51	0.54	8
					1.00	1.00	0.81	0.08	0.40	0.43	7
						1.00	0.98	0.22	0.72	0.75	6
							0.96	0.18	0.64	0.68	5
								0.89	1.00	1.00	4
									1.00	1.00	3
										1.00	2

Table 3. p-value for Tukey test of multiple comparisons: T0, TI, TII

	Hh		SB		K		Mg	
	T0	TI	T0	TI	T0	TI	T0	TI
TI	0.86		**0.00**		0.15		0.22	
TII	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**

The data at Figure 1 indicate that in soil of experimental treatments represented the 9th term of incubation the values of SB increased and at the same time the values of the Hh decreased. The results of analysis of variance indicate significant changes of hydrolytic acidity values during the time as well as significant influence of the soils with different compost doses, Tab.1.

In order to check the character of these changes the HSD Tukey test was done. There were significant differences of Hh values in soil between 12th term and 5 th, 8 th, 9th, likewise 3rd term and term 5th and 9th. Besides, the hydrolytic acidity values found at soil in 1st term were significantly different from those values obtained in soil in terms 5-9th, Tab. 2.

Furthermore, the highest contents of available Mg and K were found in soil with and without compost addition at the end of incubation after 9th term, Fig. 1. There were significant differences in potassium amounts between terms and between different doses of compost, Tab. 1. We noticed significant differences of potassium level in all soils between 11 and 2nd, and also 12 and 2nd terms, Tab. 2. Additionally, there were not significant differences with respect to the content of available potassium assessed in control soil and soil TI, but simultaneously the amounts of nutrients found in soil TII significantly differs from the amounts obtained for soil T0, TI, Tab. 3. The results of analysis of variance indicate significant changes of magnesium during the time as well as significant influence of soil with different compost doses, Tab. 1. To determine the character of these changes the HSD Tukey test was done. Magnesium content in soil represented 9th term of incubation significantly differs from the amount of nutrient found in 3rd, 10th, 11st and 12nd terms. Moreover, significant differences of Mg amounts were assessed between 7th and 10th, furthermore 7th and 12nd terms, Tab. 2. Furthermore, obtained results indicate significant differences of mean content of Mg between soils with different doses of compost: the content of Mg in T0 and TI differs from the content of Mg in TII, Tab. 3. In reflect of above presented results, it should be pointed out that introduced compost into the soil is both valuable source of nutrients and important buffer factor. In this aspect, obtained results are consistent with literature. Rezig et al. (2014) observed enhanced level of K decomposition as well as Mg after fertilization with sewage sludge. The possible explanation of such phenomenon is attributed to K existence in the cell fluid as non-structural components. The release of Mg and K was also related to mass loss trend. Therefore, increase in mass loss with the increase in nutrient content in the soil resulted in increase in Mg and K decomposition rate from the compost. The above results indicate that regardless of experiment treatment, the pattern of changes of analysed soil properties was similar.

It may result from mature nature of compost, which after composting process becomes a long lasting fertilizer, slowly subjected to decomposition process. It is well know that soil organic matter differs from compost organic matter but the significance role of native soil organic matter should be considerate and underlined, especially in reflect of obtained results. Despite of this common knowledge, the influence of the compost on soil properties was noticed and expressed by significant correlations. In order to set down the relations between properties of soils with different doses of composts, the correlation matrices are determined.

Table 4. Correlations between properties of soil in relation to treatments

	T0				TI				TII			
	Hh	SB	K	Mg	Hh	SB	K	Mg	Hh	SB	K	Mg
pH	-0.22	0.06	**-0.71**	-0.19	-0.36	0.44	-0.37	0.29	**-0.65**	0.23	**0.69**	**0.81**
Hh		-0.37	0.06	**-0.61**		-0.46	0.19	**-0.71**		-0.04	**-0.72**	-0.52
SB			0.23	**0.57**			0.04	**0.61**			0.28	0.55
K				0.52				-0.30				**0.74**

In conditions of soil incubated with the higher dose of compost (TII) the significant positive correlation with the content of available Mg and K was assessed. The values of Hh negatively correlated with amount of available Mg (T0, TI) and with available K (TII), Tab. 4. For significant correlated properties, the regression coefficients are determined. The values of physic-chemical properties as follows: pH, Hh and SB (dependent variables) habitual influence on the contents of available nutrients, especially: Mg and K (independent variables), Tab. 5.

Table 5. The regression coefficients for properties for soils with three compost doses

	Relation	β_{0ik}	β_{1ik}
T0	K(pH)	1123.30	-136.04
	Mg(Hh)	148.69	-9.30
	Mg(SB)	5.46	2.07
TI	Mg(Hh)	116.89	-2.67
	Mg(SB)	97.87	0.07
TII	Hh(pH)	75.51	-9.92
	K(pH)	-317.66	109.93
	Mg(pH)	-712.45	127.39
	K(Hh)	491.23	-7.62
	Mg(K)	-156.82	0.72

4. Conclusions

Application compost at higher dose (120 Mg) had a significant impact on soil quality parameters as Hh, SB and available amounts of potassium and magnesium. Statistical analysis proved significance of observed differences in content of all considered properties between TII and TI, TII and T0. Compost prepared on the basis of sewage sludge turned out as a slowly decomposed fertilizer, because explicit changes of some investigated properties were observed in soil at the end of incubation process i.e. at 8th and 9th term.

References

Bustamante M.A., Said-Pullicino D., Paredes C., Cecilia J.A., Moral R. (2010). Influences of winery-distillery waste compost stability and soil type on soil carbon dynamic in amended soils. *Waste Manage.* 30, 1966-1975.

Duong T.T.T., Verma S.L., Penfold C., Marschner P. (2013). Nutrient release from compost into surrounding soil. *Geoderma* , 42-47, 195-196.

Elandt R. (1964). Statystyka matematyczna w zastosowaniu do doświadczalnictwa rolniczego. *Państwowe Wydawnictwo Naukowe, Warszawa.*

Giannakis G.V., Kourgialas N.N., Paranychianakis N.V., Nikolaidis N.P., Kalogerakis N. (2014). Effects of municipal solid waste compost on soil properties and vegetables growth. *Compost Scie. Util.* 22, 116-131.

Jakubus M. (2013a). Evaluation of maturity and stability parameters of composts prepared with sewage sludge. *Fresen. Environ. Bull*. 22, 11a, 3398-3414

Jakubus M. (2013b). Wybrane zagadnienia z gleboznawstwa i chemii rolnej. Wydanie II rozszerzone i uaktualnione, Poznań. *Uniwersytet Przyrodniczy w Poznaniu.* [In Polish]

Platt Cz. (1978). Problemy rachunku prawdopodobieństwa i statystyki matematycznej. *Państwowe Wydawnictwo Naukowe, Warszawa.*

Rezig F.A.M., Elhadi E.A., Abdalla M.R. 2014. Decomposition and nutrient release pattern of wheat (*Triticum aestivum*) resiudes under different treatments in desert field conditions of Sudan. *Int J Recycl Org Waste Agricult* 3, 69, DOI 10.1007/s40093-014 0069-8.

Rigby H., Clarke B. O., Pritchard D. L., Meehan B., Beshah F., Smith S. R., Porter N. A. (2016). A critical review of nitrogen mineralization in biosolid-amended soil, the associated fertilizer value for crop production and potential for emissions to the environment. *Sci. Total Environ.* 541, 1310-1338.

Sciubba L., Cavani L. Negroni A., Zanaroli G., Fava F., Ciavatta C., Marzadori C. (2014). Changes in the functional properties of a sandy loam soil amended with biosolids at different application rates. *Geoderma* 221-222, 40-49.

Thematic Strategy for Soil Protection. *Commission staff working document. Communication from the commission to the council, the European parliament, the European economic and social committee and the committee of the regions.* COM(2006) 231.

Weber J., Kocowicz A., Bekier J., Jamroz E., Tyszka R., Debicka M., Parylak D., Kordas L. (2014). The effect of a sandy soil amendment with municipal solid waste (MSW0 compost on nitro gen uptake efficiency by plants. *European J. Agronomy* 54, 54-60.