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EFFECT OF ORGANIC FERTILISATION WITHOUT AND WITH ADDITION OF ACTIVATING SUBSTANCE PRP Sol ON SOME SOIL FERTILITY INDICES

WPŁYW NAWOŻENIA ORGANICZNEGO BEZ I Z DODATKIEM SUBSTANCJI AKTYWUJĄCEJ PRP Sol NA NIEKTÓRE WSKAŹNIKI ŻYZNOŚCI GLEBY

Abstract: A field experiment was carried out at the Agricultural Experimental Station in Lipnik in 2008–2009 on the soil belonging to soil quality class IV_a and good rye agricultural suitability complex (5). The compost applied in this study was produced by the GWDA method at the Municipal Sewage Treatment Plant in Stargard Szczecinski. It was characterised by neutral reaction (pH_{H_2O} 7.15). The total content of macroelements and heavy metals, which limits the possibility of using it for fertilisation purposes, did not exceed the standards specified in the Regulation of the Minister of Agriculture and Rural Development [Official Journal of Laws of 2008 No. 119, item 765]. Compost doses were established based on total nitrogen content. The experiment was conducted with two rotations without and with addition of active substance PRP Sol. In autumn 2007, respective compost doses were introduced into soil in the designated experimental plots according to the study design. Active substance PRP Sol was introduced into soil at a dose of 150 kgN · ha^{-1} before sowing or planting the test plants. In 2008 and 2009, the whole experimental area was fertilised with multicomponent fertiliser Polifoska 6 at a dose of 200 kg · ha^{-1} and urea (46 % N), as topdressing, at a dose of 100 kgN · ha^{-1}. Test plants were winter wheat of the cultivar *Korweta* in 2008 and spring rape of the cultivar *Bosman* in 2009.

The activating substance PRP Sol being applied against the control object and those with increasing doses of municipal sewage sludge compost did not significantly affect an increase in the total content of macroelements in soil but contributed to an average increase in the content of phosphorus, potassium, magnesium and sulphur in soil by 26.6 %, 4.84 %, 21.7 % and 38.9 %, respectively, when compared with that before setting up this experiment. The average content of assimilable nutrients in soil in the objects being fertilised with increasing doses of municipal sewage sludge compost without and with addition of activating

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substances PRP Sol in case of phosphorus and potassium was very high and high, which means that an increase occurred in soil abundance by one class.

Keywords: municipal sewage sludge, compost, activating substance PRP Sol, soil, total and assimilable phosphorus, potassium, magnesium and sulphur contents

Introduction

Sharp increase in mineral fertiliser prices has contributed to acquisition of new and cheap sources of organic matter and nutrients for plants. Therefore, organic and organic-mineral substances are being applied to determine their effect on soil fertility indices and plant yield quantity and quality as well as their environmental impact.

Municipal sewage sludge and composts being produced from it are a source of organic matter and some macroelements [1–11]. Therefore, they are characterised by high manurial value and it is recommended to apply them as organic fertilisers to enrich soil [12–17]. They must, however, meet the standards specified in the Regulation of the Minister of Environment [18] to have no negative environmental impact. Numerous studies indicate that they have a favourable effect on relationships between the "soil culture" and its chemical and physical properties and biological activity [19–21].

Activating substance PRP Sol pellet is composed of 30 % CaO, 8 % MgO, 3.5 % Na and 3–5 % premixes, with which 48 microelements is being introduced into soil (among others manganese, lead, iron, boron, and molybdenum). The content of respective PRP Sol components contributes to, among others, improving soil physical properties, induces the conversion of sparingly available phosphorus, potassium and magnesium into compounds that can be available for plants, and enriches the soil with micro-elements necessary for plant development [22–23].

Composts produced from municipal sewage sludge being used for soil fertilisation may improve the environmental balance of organic matter and nutrients. Reaction changes have an effect on the activation or retrogradation of many nutrients in soil necessary for plants. Therefore, it is reasonable to carry out research on the effect of composts with activating substance PRP Sol addition on physicochemical changes in mineral soils.

The carried out study aimed at determination of the effect of fertilisation with increasing doses of organic fertiliser without and with addition of active substance PRP Sol on total and assimilable phosphorus, potassium, magnesium and sulphur contents in soil during a 2-year study period.

Material and research methods

The Agricultural Experimental Station (AES) in Lipnik is situated on complete and incomplete brown acid soils (soil quality class V and IVa and IVb, respectively). A field experiment was set up and conducted at this station. The soil on which this field experiment was carried out at the AES in Lipnik is included among incomplete brown soils, formed from silty light loamy sand, with a medium deeply underlying layer of sandy loam. It belongs to soil quality class IVa and good rye agricultural suitability

complex (5). The carried out examination of arable layer soil (0–25 cm) showed that assimilable phosphorus richness of that soil was high (78.2 mg · kg^{-1} d.m.), while that of potassium and magnesium was average (113.9 and 38.6 mg · kg^{-1} d.m, respectively). This soil was characterised by a reaction similar to the neutral one (pH_{KCl} 6.65), its organic carbon content amounted to 7.55, while that of nitrogen, phosphorus, potassium, calcium, magnesium and sulphur to 0.64, 1.10, 2.41, 2.18, 0.60 and 0.12 g · kg^{-1} d.m., respectively.

The municipal sewage sludge compost applied in this experiment was produced by the GWDA method at the Municipal Sewage Treatment Plant in Stargard Szczeciński. It was characterised by neutral reaction (pH_{H_2O} 7.15) and contained more nitrogen and phosphorus (28.6 and 12.0 g · kg^{-1} d.m., respectively) when compared with potassium (6.70 g · kg^{-1} d.m.). The magnesium content was 2.22 g · kg^{-1} d.m., while that of calcium 4.80 g · kg^{-1} d.m. The carbon-to-nitrogen ratio amounted to 8.60 and was slightly narrowed. The total content of heavy metals, which limits the possibility of using it for fertilisation purposes, did not exceed the standards specified in the Regulation of the Minister of Agriculture and Rural Development [18].

Test plants in the experiment being conducted were winter wheat of the cultivar *Korweta* in 2008 and spring rape of the cultivar *Bosman* in 2009. This experiment included two factors: factor A – increasing compost doses, and factor B – increasing compost + PRP Sol doses. A control was the object without fertilisation (control I) and that with addition of active substance PRP Sol (control II). The study design included three doses of municipal sewage sludge compost. The size of compost dose was determined at a level corresponding to 100, 200 and 300 kgN · ha^{-1}, respectively.

In autumn 2007, respective compost doses were introduced into soil in the designated experimental plots according to the study design. In March 2008 and 2009, the whole experimental area was fertilised with multicomponent fertiliser Polifoska 6 at a dose of 200 kg · ha^{-1}. Due to low nitrogen content in multicomponent fertiliser Polifoska 6 (6 % N), additional nitrogen fertilisation was applied in the form of urea (46 % N) as the topdressing at a dose of 100 kgN · ha^{-1}. The total dose of nitrogen under spring rape and winter wheat was divided into two equal parts, applying them at two times (spring – 50 % of this dose before sowing spring rape and 50 % of it before inter-row spacing, and 50 % at the start of vegetation under winter wheat and 50 % in the shooting stage). Active substance PRP Sol was introduced into soil at a dose of 150 kgN · ha^{-1} before sowing the test plants. In autumn 2008 and 2009, the same agrotechnical measures were performed in the field experiment being carried out. Soil samples for chemical analyses were collected from the arable layer (0–25 cm) each year after completion of the vegetation period. In the soil being examined, total and assimilable phosphorus, potassium, magnesium and sulphur contents were determined. Each year, after harvesting test plant, the content of macroelements was determined in soil in averaged samples from four replications for each fertilisation object. Sulphur contents were determined on a Coestech CNS elemental analyser, while that of assimilable phosphorus and potassium forms by the Egner-Riehm method, assimilable magnesium content according to the Polish standard PN-R-04024, total phosphorus content according to the Polish standard PN-98/C-04537-14, total potassium content by the

method of flame photometry content by the method of *atomic absorption spectrometry* (AAS) on a Perkin Elmer AAS 300 spectrometer, sulphur and sulphate nephelometric method. The stock solution was obtained after previous wet mineralisation of soil material according to the Polish standards PN-ISO 11466 and PN-ISO 11047.

Total contents of assimilable of macroelements was processed statistically by the analysis of variance method using Statistica 8.0 PL computer software package. In case of significant differences, the Tukey's test was used at significance level $p = 0.05$.

Results and discussion

After completion of two-year study, some soil fertility properties were determined in average samples of each experimental object. Study results are presented in Tables 1 and 2 and Fig. 1 and 2. The findings are compared with the results of examinations being performed before starting the experiment.

Total phosphorus, potassium, magnesium and sulphur contents in soil in the control object after two years of experiment were smaller than or equal to those before starting the study (Table 1). Introduction of the first dose of municipal sewage sludge compost into soil induced an increase in phosphorus, potassium, magnesium and sulphur contents by 12.9 %, 5.43 %, 11.7 % and 8.33 %, respectively, while increased slightly the total content of macroelements in soil when compared with the control. Application of the second and the third dose of municipal sewage sludge compost induced a slight increase in the content of chemical elements being discussed in soil when compared with the first dose. Significant effect of organic fertilisation was observed in the increased total phosphorus and magnesium contents in soil.

The total contents of chemical elements under discussion in soil in the fertilisation objects with increasing doses of municipal sewage sludge compost with addition of active substance PRP Sol were higher than before setting up this experiment. Sewage sludge and composts being produced from it are abundant with phosphorus and therefore the content of that chemical element in the humus horizon of soil increases after their application. According to Grzywanowicz [24] and Czekala [25], this increase may be persist in the first year as well as in the next years after application of organic fertilisation. Wojcikowska-Kapusta et al [26] suggest that possibility of total phosphorus accumulation in soil should be taken into account. This phenomenon is induced by high calcium and magnesium contents in compost, which affects not only the pH_{KCl} value but also the formation of sparingly soluble phosphorus compounds. The obtained drops in assimilable potassium content in soil are associated with low content of that chemical element in sewage sludge and composts produced from it [1, 25, 27].

The activating substance PRP Sol being applied against the control object and that with increasing doses of municipal sewage sludge compost did not significantly affect an increase in the total content of macroelements in soil but contributed to an average increase in the content of phosphorus, potassium, magnesium and sulphur in soil by 26.6 %, 4.84 %, 21.7 % and 38.9 %, respectively, when compared with that before setting up this experiment (Table 1).

Table 1

Effect of increasing doses of municipal sewage sludge compost and activating substance PRP Sol on total phosphorus, potassium, magnesium and sulphur contents in soil after completion of the experiment

Fertilisation variants	Years	Total content [g · kg^{-1} d.m.]			
		P	K	Mg	S
Initial values		**1.10**	**2.41**	**0.60**	**0.12**
I dose of compost without PRP Sol	2008	1.21	2.60	0.64	0.13
	2009	1.34	2.45	0.71	0.14
Mean		**1.27**	**2,52**	**0.67**	**0.13**
II dose of compost without PRP Sol	2008	1.28	2.68	0.68	0.14
	2009	1.34	2.51	0.73	0.15
Mean		**1.31**	**2.59**	**0.70**	**0.14**
III dose of compost without PRP Sol	2008	1.32	2.52	0.71	0.16
	2009	1.39	2.60	0.76	0.20
Mean		**1.35**	**2.56**	**0.73**	**0.18**
I dose of compost with PRP Sol	2008	1.34	2.45	0.65	0.13
	2009	1.38	2.49	0.75	0.15
Mean		**1.36**	**2.47**	**0.70**	**0.14**
II dose of compost with PRP Sol	2008	1.39	2.48	0.70	0.15
	2009	1.41	2.55	0.75	0.17
Mean		**1.40**	**2.51**	**0.72**	**0.16**
III dose of compost with PRP Sol	2008	1.41	2.53	0.75	0.18
	2009	1.44	2.68	0.80	0.22
Mean		**1.42**	**2.60**	**0.77**	**0.20**
Control	2008	1.12	2.38	0.60	0.11
	2009	1.15	2.40	0.62	0.13
Mean		**1.13**	**2.39**	**0.61**	**0.12**
Control with PRP Sol	2008	1.18	2.42	0.66	0.14
	2009	1.20	2.44	0.68	0.15
Mean		**1.19**	**2.43**	**0.67**	**0.14**
$LSD_{0.05}$					
A – compost doses		0.06	n.s.	0.05	n.s.
B – PRP Sol fertilisation		n.s.*	n.s.	n.s.	n.s.
A × B		n.s.	n.s.	n.s.	n.s.

* n.s. – non-significant.

The content of plant-assimilable phosphorus, potassium and magnesium in soil from the control object, as well as that of sulphate sulphur, was lower than their contents before starting the study (Table 2 and Fig. 1).

Table 2

The effect of increasing doses of municipal sewage sludge compost and activating substance PRP Sol on assimilable phosphorus, potassium, magnesium and sulphate sulphur contents in soil after completion of the experiment

Fertilisation variants	Years	Content assimilable [g · kg^{-1} d.m.]			
		P	K	Mg	S
Initial values		**78.2**	**113.9**	**38.6**	**9.26**
I dose of compost without PRP Sol	2008	103.4	125.9	42.7	9.85
	2009	89.9	115.2	54.9	10.3
Mean		**96.6**	**120.2**	**48.8**	**10.1**
II dose of compost without PRP Sol	2008	110.6	137.6	46.6	9.98
	2009	92.5	119.0	54.2	10.2
Mean		**101.5**	**128.3**	**49.9**	**10.4**
III dose of compost without PRP Sol	2008	120.4	141.7	48.3	10.8
	2009	100.0	122.5	53.5	12.1
Mean		**110.2**	**132.1**	**50.9**	**11.5**
I dose of compost with PRP Sol	2008	115.0	145.5	43.1	9.90
	2009	102.0	125.7	56.1	10.7
Mean		**108.5**	**135.6**	**49.6**	**10.3**
II dose of compost with PRP Sol	2008	119.7	149.3	47.8	10.9
	2009	110.5	133.9	54.8	11.4
Mean		**115.1**	**141.6**	**51.3**	**11.2**
III dose of compost with PRP Sol	2008	124.6	147.1	49.9	11.6
	2009	115.6	138.5	53.7	12.0
Mean		**120.1**	**142.8**	**51.8**	**11.8**
Control	2008	75.6	112.3	36.1	8.90
	2009	74.4	111.9	39.0	9.00
Mean		**75.0**	**112.1**	**36.5**	**8.96**
Control with PRP Sol	2008	84.1	114.9	37.2	9.18
	2009	84.9	114.1	37.8	9.22
Mean		**84.5**	**114.5**	**37.5**	**9.20**
$LSD_{0.05}$					
A – compost doses		12.3	13.1	7.21	0.68
B – PRP Sol fertilisation		6.23	6.30	n.s.*	0.34
A × B		n.s.	n.s.	n.s.	n.s

* n.s. – non-significant.

Introduction of the first dose of municipal sewage sludge compost induced an increase in the content of plant-assimilable phosphorus, potassium, magnesium and sulphate sulphur in soil when compared with the control object. The content of plant-assimilable macroelements increased by 21.6, 8.1, 12.3 and 1.14 mg · kg^{-1} d.m.,

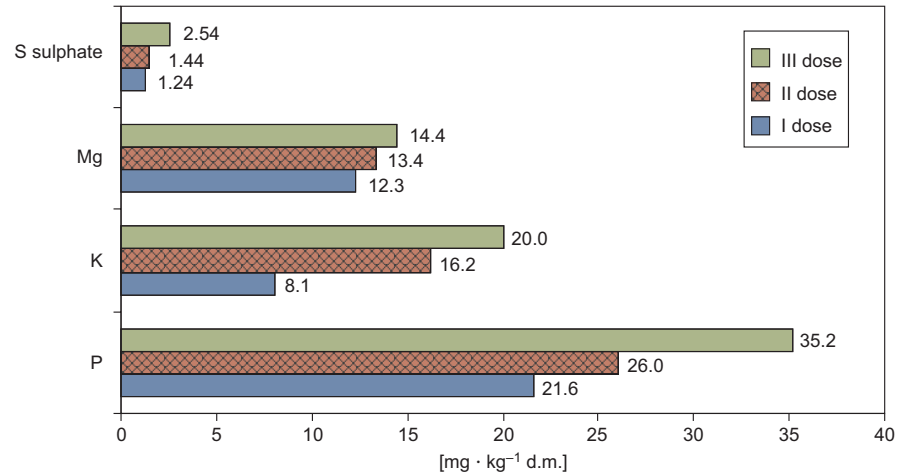

Fig. 1. Increase in plant-assimilable phosphorus, potassium, magnesium and sulphate sulphur contents in soil obtained as affected by increasing doses of municipal sewage sludge compost after completion of the study

respectively, for phosphorus, potassium, magnesium and sulphate sulphur. Similar effect was obtained after introduction of the second dose of municipal sewage sludge compost; assimilable phosphorus, potassium, magnesium and sulphate sulphur contents increased, respectively, by 26.5, 16.2, 13.4 and 1.44 mg · kg^{-1} d.m. soil when compared with the control object. Fertilisation with the third dose of municipal sewage sludge compost induced a further increase (as compared with the control object) in plant--assimilable phosphorus, potassium, magnesium and sulphate sulphur contents by 35.2, 20.0, 14.4 and 2.54 mg · kg^{-1} d.m. soil, respectively (Fig. 2).

Significant increase in the content of plant-assimilable phosphorus, potassium, magnesium and sulphur was observed in the fertilisation objects with exclusive application of organic fertilisation. The activating substance PRP Sol being introduced into soil contributed to a significant increase in potassium, phosphorus and sulphur contents in soil.

Summing up, it is possible to state that the content of plant-assimilable phosphorus in soil increased to the greatest extent after application of municipal sewage sludge compost (by 37 %),followed by that of magnesium (by 36.7 %), sulphate sulphur (by 19.5 %) and potassium (by 13.2 %), when compared with the control object (Table 2). These results show that plant-assimilable phosphorus and potassium forms had been introduced into soil together with municipal sewage sludge compost. Part of the plant-assimilable phosphorus and potassium forms could have also come from further decomposition of the composting mass in soil. The obtained results find their confirmation in the studies indicating a possibility of using municipal sewage sludge for fertilisation purposes [24, 28–32]. On the other hand, the activating substance PRP Sol being applied against the control object and the increasing compost doses increased the content of plant-assimilable phosphorus and potassium in soil in the study by Bourguignon [32].

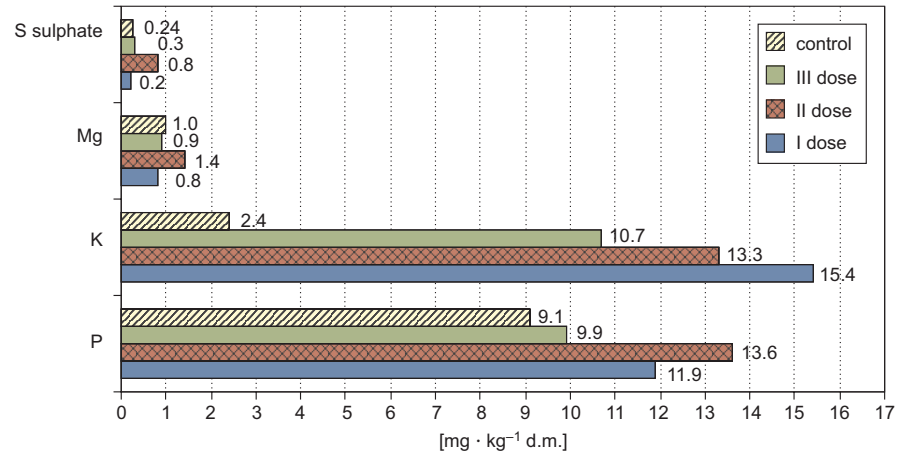

Fig. 2. The effect of activating substance PRP Sol being applied in the control object and those fertilised with increasing doses of municipal sewage sludge compost on the increase in plant-assimilable phosphorus, potassium, magnesium and sulphate sulphur contents in soil. Data are given in mg · kg^{-1} d.m.

Based on the data given in Table 2, the effect of activating substance PRP Sol being applied in the control object and in those fertilised with increasing doses of municipal sewage sludge compost on plant-assimilable phosphorus, potassium, magnesium and sulphate sulphur contents in soil was estimated. Results of these calculations are presented in Fig. 2.

The application of activating substance PRP Sol in the control object and in those being fertilised with increasing dosed of municipal sewage sludge compost affected an increase in plant assimilable phosphorus, potassium, magnesium and sulphate sulphur concentrations in soil. The content of plant-assimilable phosphorus in soil increased to the greatest extent (on average by 11.1 mgP · kg^{-1} d.m. soil), followed by that of potassium (on average by 10.4 mgK · kg^{-1} d.m. soil), magnesium (on average by 1.02 mgMg · kg^{-1} d.m. soil) and sulphate sulphur (on average by 0.38 mgS-SO_4 · kg^{-1} d.m. soil) – see Fig. 2.

When evaluating the average content of assimilable nutrients in soil with the method of threshold limit values used by Chemical and Agricultural Research Laboratories, it was found that assimilable phosphorus and potassium contents were very high and high in the objects being fertilised with increasing doses of municipal sewage sludge compost without and with addition of active substance PRP Sol, which means that an increase occurred in soil abundance by one class. The content of assimilable magnesium in soil was medium, which means that no changes in soil abundance class were observed.

Conclusions

1. Application of a single dose of municipal sewage sludge compost induced an increase in phosphorus, potassium, magnesium and sulphur contents in soil. Application

of the second and the third dose of municipal sewage sludge compost contributed to a slight increase in the content of chemical elements under discussion in soil when compared with the first dose. Significant effect of organic fertilisation was only observed in an increase in phosphorus and magnesium contents in soil.

2. The activating substance PRP Sol being applied against the control object and those with increasing doses of municipal sewage sludge compost did not significantly affect an increase in the total content of macroelements in soil.

3. Significant increase in the content of plant-assimilable phosphorus, potassium, magnesium and sulphur was observed in the fertilisation objects with exclusive application of organic fertilisation. The activating substance PRP Sol being introduced into soil contributed to a significant increase in potassium, phosphorus and sulphur contents in soil.

4. The content of plant-assimilable phosphorus content in soil increased to the greatest extent after application of municipal sewage sludge compost, followed by that of magnesium, sulphate sulphur and potassium, when compared with the control object.

5. When evaluating the average content of assimilable nutrients in soil with the method of threshold limit values, it was found that assimilable phosphorus and potassium contents were very high and high in the objects being fertilised with increasing doses of municipal sewage sludge compost without and with addition of active substance PRP Sol, which means that an increase occurred in soil abundance by one class.

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WPŁYW NAWOŻENIA ORGANICZNEGO BEZ I Z DODATKIEM SUBSTANCJI AKTYWUJĄCEJ PRP Sol NA NIEKTÓRE WSKAŹNIKI ŻYZNOŚCI GLEBY

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Abstrakt: Doświadczenie polowe przeprowadzono w latach 2008–2009 na terenie RSD w Lipniku na glebie zaliczanej do klasy bonitacyjnej IV_a, kompleksu przydatności rolniczej żytniego dobrego (5). Do badań użyto kompostu wyprodukowanego w Komunalnej Oczyszczalni Ścieków w Stargardzie Szczecińskim. Charakteryzował się odczynem obojętnym (pH_{H_2O} 7.15). Zawartość ogólna makroskładników i metali ciężkich, która limituje możliwość wykorzystania go do celów nawozowych nie przekraczała norm podanych w Rozporządzeniu Ministra Rolnictwa i Rozwoju Wsi [DzU 08.119.765]. Dawki kompostu ustalono na podstawie zawartości azotu ogólnego. Doświadczenie prowadzono w dwóch rotacjach bez i z dodatkiem substancji aktywnej PRP Sol. Jesienią 2007 r. zgodnie ze schematem badań na wyznaczonych poletkach wprowadzono do gleby odpowiednie dawki kompostu. Substancję czynną PRP Sol w dawce 150 kg · ha^{-1} stosowano przed siewem lub sadzeniem roślin testowych. Całą powierzchnię doświadczenia w 2008 i 2009 roku nawożono Polifoską 6 w dawce 200 kg · ha^{-1} oraz pogłównie w formie mocznika (46 % N) w dawce 100 kgN · ha^{-1}. Roślinami testowymi były: w 2008 roku pszenica ozima odmiany *Korweta,* a 2009 rzepak jary odmiany *Bosman*.

Substancja aktywująca PRP Sol stosowana na tle obiektów: kontrolnego oraz ze wzrastającymi dawkami kompostu z komunalnego osadu ściekowego nie miała istotnego wpływu na zwiększenie form ogólnych makroskładników w glebie, ale przyczyniła się do średniego wzrostu w glebie zawartości fosforu o 26.6 %, potasu o 4.84 %, magnezu o 21.7 % i siarki o 38.9 % w porównaniu do zawartości sprzed założenia doświadczenia. Średnią zawartość składników przyswajalnych w glebie na obiektach nawożonych wzrastającymi dawkami kompostu bez i z dodatkiem substancji aktywującej PRP Sol fosforu i potasu przyswajalnego była bardzo wysoka i wysoka, co oznacza, że nastąpił wzrost zasobności gleby o jedną klasę.

Słowa kluczowe: komunalny osad ściekowy, kompost, substancja czynna PRP Sol, gleba, zawartość ogólna i form przyswajalnych fosforu, potasu, magnezu i siarki