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EVALUATION OF THE DIRECT EFFECT AND AFTER-EFFECT OF ORGANIC FERTILISATION WITHOUT AND WITH PRP SOL ADDITION ON SOIL ENZYMATIC ACTIVITY

OCENA BEZPOŚREDNIEGO I NASTĘPCZEGO DZIAŁANIA NAWOŻENIA ORGANICZNEGO BEZ I Z DODATKIEM PRP SOL NA AKTYWNOŚĆ ENZYMATYCZNĄ GLEBY

Abstract: In a two-year field experiment (2008–2009), the effect of increasing doses of compost being produced with municipal sewage sludge without and with addition of active substance PRP Sol on the activity of urease, dehydrogenase and phosphatases was examined during cultivation of potatoes and spring wheat. The study design included a control object with standard mineral fertilisation and three doses of organic fertilisation. The size of compost doses was determined at a level corresponding to 100, 200 and 300 kg N · ha^{-1}. Organic fertilisation was performed on 28.09.2007. In 2008 and 2009, active substance PRP Sol was introduced into soil in the whole area of experimental field at a dose of 150 kg · ha^{-1} an 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 top-dressing at a dose of 80 kg N · ha^{-1} under potatoes and 100 kg N · ha^{-1} under spring wheat at two times. Soil samples for chemical analyses were collected from the arable layer (0–25 cm) from under potatoes (2008) and spring wheat (2009) twice during cultivation of test plants. The carried out study shows that urease activity in soil at soil sample collection times I and II increased on average by 13.2 %, that of phosphatases by 20.2 % and of dehydrogenase by 17.96 % as affected by a single, a doubled and a tripled dose of municipal sewage sludge compost being introduced into soil, whereas in the objects fertilised in addition with PRP Sol respectively by 15.4 %, 35.1 % and 18.65 % when compared with control object without PRP Sol. The applied organic fertilisation with active substance PRP Sol stimulated the enzymatic activity of urease, dehydrogenase and phosphatases in all fertilisation objects when compared with the control one.

Keywords: compost, active substance PRP Sol, soil activity of urease, dehydrogenase and phosphatases

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The level of soil enzymatic activity is a sensitive indicator in evaluation of its fertility and capability. Soil enzymatic activity depends to a large extent on optimum moisture and air access to soil, its reaction, heavy metals accumulation, fertilisation, and agrotechnical measures being performed [1–5]. The activity of urease, dehydrogenase, phosphatases and other soil enzymes depends also on soil type, its physicochemical properties as well as on the species of plant being grown on it and its growth and development stage [6–9].

Heavy rise in prices for mineral fertilisers, decreased production of natural fertilisers induced by led to the search for cheaper and environmentally safer sources of nutrients for plants and organic matter for soils.

The manurial value of sewage sludges and composts being produced with them shows that they can be used for soil fertilisation (considerable content of nutrients for plants and organic matter) [10–13]. Attention has been also paid to the possibility of using municipal sewage sludges to produce organic fertilisers which can result in an increase in soil fertility and capability. The application of compost produced with sewage sludge as an organic fertiliser constitutes a valuable source of organic matter. These fertilisers are characterised by a considerable amount of nitrogen and phosphorus, while the content of heavy metals does not exceed the limit values allowing them to be used for environmental and agricultural purposes [14].

Changes in soil environment depend to a greater extent on the activity of respective soil enzymes converted into organic carbon units than on the activity expressed in substrate units per soil mass unit [8]. Results of the studies carried out so far demonstrate that organic and natural fertilisation play a very important part as it determines the carbon content in soil and is in general positively correlated with the activity of enzymes [3, 15, 16].

The studies carried out so far have also shown that active substance PRP Sol contributes, among others, to the improvement of soil physical properties, increases its enzymatic activity and induces the conversion of sparingly available phosphorus, potassium and magnesium forms into compounds which are available for plants [17].

This study aimed at determination of the direct effect and after-effect of organic fertilisation (compost) being applied without and with addition of active substance PRP Sol on the activity of soil enzymes at two soil sample collection times during potato and spring wheat cultivation and after their harvest (2008 and 2009, respectively).

Material and research methods

A field experiment was carried out at the Agricultural Experimental Station in Lipnik belonging to the Western Pomeranian University of Technology in Szczecin. Examinations were performed in 2008 and 2009. The municipal sewage sludge compost being used in examinations 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) and contained decidedly more nitrogen (28.6 g · kg^{-1} d.m.) and phosphorus (12.0 g · kg^{-1} d.m.) when compared to potassium (6.70 g · kg^{-1} d.m.). The total content of heavy metals, which determines the possibility of using it for fertilisation purposes, did not exceed the standards given in the Regulation of the Minister of Agriculture and

Rural Development [18]. The experiment was set up on a field which was characterised by brown, incomplete soil, formed from silty light loamy sand, medium deeply underlaid by sandy loam, of soil quality class IVa and good rye agricultural suitability complex. Soil samples from the field experiment were collected for examinations from the arable layer 0–25 cm. This soil was characterised by a reaction approximating a neutral one (pH_{KCl} 6.65), its organic carbon richness amounted to 7.55, while total nitrogen, phosphorus, potassium, calcium, magnesium and sulphur contents to 0.64, 1.10, 2.41, 2.18, 0.60 and 0.12 g · kg^{-1} d.m., respectively.

The design of field experiment included a control object with standard mineral fertilisation and three doses of organic fertilisation. The size of compost doses was determined at the level corresponding to 100, 200 and 300 kg N · ha^{-1}. Experiment was conducted without and with addition of active substance PRP Sol. Increasing compost doses were introduced into soil on respective fertilisation objects in autumn 2007. In 2008, test plants were potatoes of the cultivar Ikar, while spring wheat of the cultivar Tybalt in 2009.

In 2008 and 2009, the whole area of experimental field was fertilised with active substance PRP Sol at a dose of 150 kg · ha^{-1} and 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 80 kg N · ha^{-1} under potatoes and 100 kg N · ha^{-1} under spring wheat at two times. The total dose of nitrogen under spring wheat was divided into two equal parts, applying it at two times (spring – 50 % of this dose before planting or sowing test plants and 50 % of it under spring wheat in the shooting stage or under potatoes during the second ridging).

Soil samples for chemical analyses were collected from the arable layer (0–25 cm) at two times, *ie* twice in 2008 from under potatoes: I – 30 days after planting potato tubers (15.05.2008), and II – after harvesting potato tubers (30.09.2008), while in 2009 spring wheat of the cultivar Tybalt was sown on the same field in spring. Soil samples from under spring wheat were also collected at two times: I – 30 days after sowing (18.04.2009), and II – after harvesting spring wheat (16.08.2009).

Dehydrogenase activity was determined colorometrically with Lambda 150 spectrophotometer at a wavelength of 485 nm after 24-hour incubation at 30 ^{o}C with TTC solution according to the method of Thalman [19]. The activity of urease was determined according to the method of Zantua and Bremner [20], consisting in spectrophotometric measurement of emitted ammonia after soil sample incubation with 2.5 % urease as a substrate at 37 ^{o}C, while that of phosphatases according to the method of Tabatabai [21].

Statistical analysis of the findings was performed using Statistica 8.0 computer software package, whereas differences between mean values were evaluated with the Tukey's test at significance level $p = 0.05$.

Results and discussion

Urease and dehydrogenase activities at two soil sample collection times are compared in Tables 1, 2 and 3. The increasing doses of compost without and with PRP

Sol addition and soil sample collection times in both years of the experiment significantly affected the activity of urease, dehydrogenase and phosphatases.

The findings show that urease activity increased on average by 13.2 %, that of phosphatases by 20.2 % and dehydrogenase activity by 18.0 % as affected by the increasing doses of municipal sewage sludge compost at soil sample collection time I and II, whereas by 15.4 %, 35.1 % and 18.6 %, respectively, in the objects being additionally fertilised with active substance PRP Sol, when compared with control object without PRP Sol addition (Tables 1, 2 and 3).

Factors affecting the variability of enzymatic processes in soil during the vegetation period of test plants are the changing temperature and the amount of atmospheric precipitation [22]. Soil enzymes are decidedly more active at the end of springtime and at the beginning of summer and autumn [23]. Higher dehydrogenase activity was observed in the soil collected in 2009 at soil sample collection times I and II when compared with 2008. The obtained study results are most probably related to air temperature which amounted to 18.7 ^{o}C in August 2008 and 19.3 ^{o}C in 2009, whereas total atmospheric precipitation was higher in 2009 (75.2 mm) when compared with 2008 (48.8 mm).

Table 1

Effect of soil sample collection time and increasing municipal sewage sludge compost doses and active substance PRP Sol on urease activity. Data are given in mg $N\text{-}NH_4 \cdot kg^{-1} \cdot h^{-1}$

Fertilisation variants	Years	Without PRP SOL	With PRP SOL	**Mean**	Without PRP SOL	With PRP SOL	**Mean**
		I times			II times		
I dose of compost	2008	14.1	14.5	**14.3**	16.2	16.3	**16.2**
	2009	13.8	14.0	**13.9**	15.8	16.1	**15.9**
	Mean	**13.9**	**14.0**	**14.1**	**16.0**	**16.2**	**16.1**
II dose of compost	2008	14.0	14.9	**14.4**	16.4	16.8	**16.6**
	2009	14.1	14.4	**14.2**	16.2	16.5	**16.3**
	Mean	**14.0**	**14.6**	**14.3**	**16.3**	**16.6**	**16.4**
II dose of compost	2008	15.1	15.8	**15.4**	16.5	16.8	**16.7**
	2009	14.8	15.2	**15.0**	16.8	16.4	**16.6**
	Mean	**14.9**	**15.5**	**15.2**	**16.6**	**16.6**	**16.6**
$LSD_{0.05}$							
I – compost doses		**1.04**			**0.14**		
II – PRP Sol fertilisation		**0.13**			**n.s.**		
I × II		**1.08**			**n.s.**		
Control	2008	13.5	13.6	**13.5**	13.8	13.9	**13.9**
	2009	13.6	13.8	**13.7**	13.5	14.0	**13.7**
	Mean	**13.5**	**13.7**	**13.6**	**13.6**	**13.9**	**13.8**

Urease activity ranged from 13.8 to 16.8 mg $N\text{-}NH_4 \cdot kg^{-1} \cdot ha^{-1}$ (Table 1). The soil samples collected in 2008 at soil sample collection time II from under potatoes showed

higher urease activity when compared with that determined in the soil samples collected from under spring wheat. The largest increase in urease activity in soil was obtained in 2008 in the object being fertilised with a doubled dose of compost without and with PRP Sol addition between soil sample collection time I and II (May, September), respectively by 17.1 % and 12.7 %. In 2009, an increase in urease activity was observed in the same fertilisation objects but a smaller one, which amounted respectively to 14.9 % and 14.58 %. The lowest urease activity was observed in the objects fertilised with a single dose of compost itself. Highly significant increase in the activity of enzyme being discussed was observed in the objects with a doubled and a tripled dose of compost without and with PRP Sol addition when compared with control object. Significant increase in urease activity in the soil being fertilised with sewage sludge or compost produced with it is confirmed by studies of other authors [24]. Soil sample collection time had a significant effect on increase in urease activity. Respective fertilisation objects were characterised by different activity levels in relation to control object. Such a differentiation in the activity of urease, *ie* of an enzyme catalysing urea decomposition, may be evidence of various mineralisation rate of nitrogen compounds in the soil samples under examination [25].

When comparing the activity of urease in soil samples, significantly larger effect of organic fertilisation without and with PRP Sol addition on the activity of enzyme being examined in the soil samples collected from under potatoes (2008) was shown when compared with the soil material collected from under spring wheat (2009).

Differences in urease activity between soil sample collection times probably result from the protective effect of mineral and organic colloids in relation to urease, producing complex compounds with them [26]. This is evidenced by more intense activity of urease in the soil with higher sorptive capacity and its positive response to compost fertilisation. Urease is strongly immobilised by organic matter but larger stability of that enzyme is ensured by composted organic mass than the fresh one [26]. Perhaps differences in urease stimulation by compost should be seen in the degree of compost organic matter decomposition. After two years of experiment, average urease activity in the soil fertilised solely with increasing compost doses amounted to 15.3 mg $N\text{-}NH_4 \cdot kg^{-1} \cdot h^{-1}$ and was higher by 1.75 unit when compared with control object (Table 1).

Dehydrogenase activity ranged from 13.1 to 16.4 cm $\cdot$ $H_2 \cdot kg^{-1} \cdot d^{-1}$. The soil samples collected in 2009 from under spring wheat showed higher dehydrogenase activity when compared with that being determined in the soil samples collected from under potatoes (2008); see Table 2.

Dehydrogenase activity in the soil samples collected in 2009 between soil sample collection time I and II (April, August) increased respectively by 3.03 % and 10.03 % as affected by the increasing doses of compost without and with PRP Sol addition being introduced into soil. On the other hand, an increase in dehydrogenase activity in 2008 in the same fertilisation objects was smaller and amounted respectively to 1.95 % and 9.00 %. The highest dehydrogenase activity in the soil samples collected from under spring wheat (2009) was characteristic of the object being fertilised with a doubled and a tripled dose of compost with PRP Sol addition, between soil sample collection time I

Table 2

Effect of soil sample collection time and increasing municipal sewage sludge compost doses and active substance PRP Sol on dehydrogenase activity. Data are given in cm · H_2 · kg^{-1} · d^{-1}

Fertilisation variants	Years	Without PRP SOL	With PRP SOL	**Mean**	Without PRP SOL	With PRP SOL	**Mean**
		I times			II times		
I dose of compost	**2008**	13.4	13.1	**13.2**	13.7	14.2	**13.8**
	2009	13.6	13.8	**13.7**	14.1	14.6	**14.3**
	Mean	**13.5**	**13.4**	**13.4**	**13.8**	**13.8**	**13.8**
II dose of compost	**2008**	14.2	13.9	**14.0**	14.4	15.1	**14.7**
	2009	14.5	14.3	**14.4**	15.0	15.4	**15.2**
	Mean	**14.3**	**14.1**	**14.2**	**14.7**	**15.2**	**15.0**
III dose of compost	**2008**	14.6	14.1	**14.3**	14.9	15.5	**15.2**
	2009	14.9	14.1	**14.5**	15.1	16.4	**15.7**
	Mean	**14.7**	**14.1**	**14.4**	**15.0**	**15.9**	**15.5**
$LSD_{(0.05)}$							
I – compost doses		**1.26**			**1.18**		
II – PRP Sol fertilisation		**n.s.**			**0.42**		
I × II		**n.s.**			**n.s.**		
Control	2008	12.1	12.6	**12.3**	12.2	12.8	**12.5**
	2009	12.0	12.4	**12.2**	12.3	12.7	**12.5**
	Mean	**12.1**	**12.5**	**12.3**	**12.2**	**12.8**	**12.5**

and II (April, August). Dehydrogenase activity in these fertilisation objects and between soil sample collection time increased respectively by 7.69 % and 16.3 %. Smaller increase in dehydrogenase activity, respectively by 3.67 % and 3.45 %, was obtained in the objects with a doubled and a tripled dose of compost itself being introduced into soil (Table 2). The applied fertilisation with a doubled and a tripled dose of compost with PRP Sol addition between soil sample collection time I and II contributed to an increase in dehydrogenase activity, respectively by 7.80 % and 12.8 %.

Dehydrogenase activity in the soil samples collected from under spring wheat (2009) was significantly higher as affected by fertilisation with the increasing doses of compost with PRP Sol addition when compared with control object. Active substance PRP Sol being introduced into soil significantly induced an increase in the enzyme under discussion in the soil material collected in 2008 and 2009.

The activity of phosphatases in the first study year (2008) was in the range of 1.11 to 1.86 mmol PNP · kg^{-1} · h^{-1}, whereas in the second one (2009) ranged from 1.20 to 1.79 mmol PNP · kg^{-1} · h^{-1} (Table 3). The soil of control object was characterised, on average of two years, by the lowest activity of that enzyme. In the soil samples collected in 2009 at soil sample collection time I (April), higher activity of phosphatases was observed when compared to 2008 (May) in the objects with a single, a doubled and a tripled dose of compost without and with PRP Sol addition, which increased on average by 6.03 %, 5.42. % and 4.89 %, respectively. On the other hand, in the soil samples

collected at soil sample collection time II after harvesting test plants (September 2008, August 2009), this correlation was opposite. Higher activity of phosphatases in all fertilisation objects was characteristic of the soil collected at soil sample collection time II in 2008 when compared to soil sample collection time II in 2009 (Table 3).

Table 3

Effect of soil sample collection time and increasing municipal sewage sludge compost doses and active substance PRP Sol on the activity of phosphatases. Data are given in mmol PNP · kg^{-1} · h^{-1}.

Fertilisation variants	Yares	Without PRP SOL	With PRP SOL	**Mean**	Without PRP SOL	With PRP SOL	**Mean**
		I times			II times		
I dose of compost	2008	1.11	1.22	**1.16**	1.36	1.56	**1.46**
	2009	1.20	1.26	**1.23**	1.31	1.47	**1.39**
	Mean	**1.15**	**1.24**	**1.19**	**1.33**	**1.51**	**1.42**
II dose of compost	2008	1.21	1.36	**1.29**	1.48	1.69	**1.58**
	2009	1.31	1.42	**1.36**	1.40	1.65	**1.53**
	Mean	**1.26**	**1.39**	**1.32**	**1.44**	**1.67**	**1.55**
III dose of compost	2008	1.38	1.48	**1.43**	1.60	1.86	**1.73**
	2009	1.41	1.59	**1.50**	1.57	1.79	**1.68**
	Mean	**1.39**	**1.53**	**1.46**	**1.58**	**1.82**	**1.70**
$LSD_{0.05}$							
I – compost doses		**0.13**			**0.100**		
II – PRP Sol fertilisation		**0.04**			**0.045**		
I × II		**n.s.**			**n.s.**		
Control	2008	1.04	1.10	**1.07**	1.20	1.34	**1.27**
	2009	1.06	1.09	**1.07**	1.22	1.30	**1.26**
	Mean	**1.05**	**1.09**	**1.07**	**1.21**	**1.32**	**1.26**

The applied fertilisation with a doubled and a tripled dose of compost with PRP Sol addition between soil sample collection time I and II contributed to an increase in the activity of phosphatases by 24.3 % and 25.7 %, respectively. Smaller increase in the activity of enzyme under discussion was obtained in the object with a single dose of compost with PRP Sol addition being introduced into soil, which amounted to 16.7 %.

Introduction of exclusive fertilisation with municipal sewage sludge compost significantly affected increase in the enzymatic activity of phosphatases between doses of that organic fertiliser. Average increase in the activity of phosphatases between dose I and III, II and III, and I and II amounted respectively to 20.8 %, 10.3 % and 9.60 %. Addition of active substance PRP Sol at a dose of 150 kg · ha^{-1} to increasing compost doses contributed to significant increase in the activity of that enzyme in the analysed soil. Increase in the activity of dehydrogenase and phosphatases in the soil where fertilisation with municipal sewage sludge compost was applied is confirmed by other

studies [27]. Many authors indicate higher enzymatic activity in soils with large sorptive capacity and larger moisture [28].

When analysing the period of two study years, average increase in the activity of phosphatases was observed between sample collection time I and II in the objects with a single, a doubled and a tripled dose of compost itself being introduced into soil, respectively by 15.6 %, 14.3 % and 13.7 %, while in the objects with compost and PRP Sol by 21.8 %, 20.1 % and 18.9 %.

Significant effect on increase in the enzymatic activity of phosphatases had organic fertilisation without and with PRP Sol addition and soil sample collection times.

Conclusions

1. Fertilisation with municipal sewage sludge compost without and with PRP Sol addition stimulates the activity of urease, dehydrogenase and phosphatases in soil. Their effect depends on the size of compost dose introduced into soil and soil sample collection time.

2. The largest increase in urease activity in soil was obtained in 2009 in the objects being fertilised with a doubled dose of compost without and with PRP Sol addition between soil sample collection time I and II.

3. The carried out study shows that urease activity in soil at soil sample collection times I and II increased on average by 13.2 %, that of phosphatases by 20.2 % and of dehydrogenase by 17.96 % as affected by a single, a doubled and a tripled dose of municipal sewage sludge compost being introduced into soil, whereas in the objects fertilised in addition with PRP Sol respectively by 15.4 %, 35.1 % and 18.65 % when compared with control object without PRP Sol.

4. Higher activity of the enzymes under examination was observed in the objects fertilised with municipal sewage sludge compost and PRP Sol addition when compared with those fertilised solely with compost.

5. The applied fertilisation with increasing doses of municipal sewage sludge compost without and with PRP Sol addition increases the activity of urease, dehydrogenase and phosphatases when compared with control object.

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OCENA BEZPOŚREDNIEGO I NASTĘPCZEGO DZIAŁANIA NAWOŻENIA ORGANICZNEGO BEZ I Z DODATKIEM PRP SOL NA AKTYWNOŚĆ ENZYMATYCZNĄ GLEBY

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Abstrakt: W dwuletnim doświadczeniu polowym (2008–2009) badano wpływ wzrastających dawek kompostu wyprodukowanego z komunalnego osadu ściekowego bez i z dodatkiem substancji czynnej PRP Sol na aktywność ureazy, dehydrogenazy i fosfataz w trakcie uprawy ziemniaka i pszenicy jarej. Schemat badań obejmował obiekt kontrolny ze standardowym nawożeniem mineralnym oraz trzy dawki nawożenia organicznego. Ilość dawek kompostu ustalono na poziomie odpowiadającym 100, 200 i 300 kg N · ha^{-1}. Nawożenie organiczne wykonano 28.09.2007 r. W latach 2008 i 2009 na całą powierzchnię doświadczenia wprowadzono substancją czynną PRP Sol w dawce 150 kg · ha^{-1} oraz Polifoskę 6 w dawce 200 kg · ha^{-1}. Ze względu na niewielką zawartość azotu w Polifosce 6 (6 % N) zastosowano pogłównie mocznik w dawce odpowiadającej 100 kg N · ha^{-1} pod ziemniaka i pszenicę jarą w dwóch terminach. Próbki glebowe do analiz chemicznych pobrano z warstwy ornej (0–25 cm) spod ziemniaka (2008 r.) i pszenicy jarej (2009 r.) dwukrotnie w okresie uprawy roślin testowych. Z przeprowadzonych badań wynika, że pod wpływem wprowadzonej pojedynczej, podwojonej i potrojonej dawki kompostu z udziałem komunalnego osadu ściekowego w I i II terminie pobierania próbek glebowych średnio w glebie zwiększyła się aktywność ureazy o 13,2 %, fosfataz o 20,2 % i dehydrogenazy o 18,0 %, natomiast na obiektach nawożonych dodatkowo PRP Sol odpowiednio o 15,4 %, 35,1 % i 18,6 % w porównaniu z obiektem kontrolnym bez PRP Sol. Zastosowane nawożenie organiczne łącznie z substancją PRP Sol stymulowało aktywność enzymatyczną ureazy, dehydrogenazy i fosfataz na wszystkich obiektach nawozowych w porównaniu do obiektu kontrolnego.

Słowa kluczowe: kompost, substancja czynna PRP Sol, aktywność w glebie ureazy, dehydrogenazy i fosfataz