MIDDLE POMERANIAN SCIENTIFIC SOCIETY OF THE ENVIRONMENT PROTECTION
ŚRODKOWO-POMORSKIE TOWARZYSTWO NAUKOWE OCHRONY ŚRODOWISKA

Annual Set The Environment Protection
Rocznik Ochrona Środowiska

Volume/Tom 20. Year/Rok 2018 ISSN 1506-218X 837-856

Assessment of the Effect of Struvite on the Growth of *Sinapis alba*

Małgorzata Worwąg
Czestochowa University of Technology

1. Introduction

Struvite has fertilizing properties and is a source of phosphorus, nitrogen and magnesium. More and more scientific studies concerning recovery of phosphorus from recycled materials have been devoted to this compound. Current research aimed at identification of optimal chemical conditions for the recovery of phosphorus in the form of struvite from various recycled materials, especially from various recycled materials, especially those generated in the wastewater treatment plant and wastewater from the meat industry (Worwąg & Mędrala 2017, Wzorek 2008, Wzorek 2008a). Raw materials which represent alternative sources of phosphorus include: sewage sludge from municipal wastewater, slaughter house waste from the meat industry, manure and liquid manure from animal production (Wzorek 2008).

Struvite can be a good fertilizer since it contains basic biogenic elements needed for plant growth. Furthermore, due to low solubility, its components are not washed to ground waters or inside the soil, thus limiting availability for plants. After previous granulation, struvite can be added to the soil with greater amounts than other fertilizers with phosphorus and it is safe for plants (Gorazda et al. 2008, Faucon et al. 2015).

Despite the benefits of using struvite as a fertilizer, the processes of its recovery have not gained much popularity to date. The processes of struvite recovery include: CSIR, Phosnix UNITIKA.

The CSIR process was developed in the South Africa and consists in crystallization in the fluidized bed. Struvite is recovered in the reactor from supersaturated solutions at pH > 8 and in the presence of yellow slate and fly ash as crystallization nuclei. NaOH was used for maintaining adequate value of pH. The CSIR process consists in removal of the compounds of phosphorus in the form of granulated struvite (Wzorek 2008, Jodko et al. 2003). In a three-step Phosnix Unitika process, precipitation of struvite occurs to greater scale. The process is conducted in the fluidized-bed reactor, where the level of magnesium and phosphorus is constantly equalized by adding Mg^{2+} in the form of magnesium chloride. The high level of pH = 9, is maintained by the addition of NaOH. The whole process takes 1 to 2h and allows for the recovery of phosphorus, even with the efficiency of 94% (Hudziak et al. 2012).

The aim of the preliminary study was to analyse the effect of addition of struvite on plant growth and chemical and physical parameters of the soil. Struvite used in the present study was obtained in laboratory settings. For this purpose, optimal concentrations were evaluated for selected ions (PO_4^{3-}, Mg^{2+}, $NH4^{+}$) at which maximal sediment mass was precipitated. Next, the surface composition of the obtained sediments was determined by means of X-ray spectra analysis.

2. Material and methods

2.1. Substrate for the analysis

The following substrates were used in the study:

- synthetic struvite, obtained in laboratory settings,
- soil from a house garden,
- mixture of soil with various struvite doses: 0.1 g, 0.5 g and 1 g to the same soil volume.

2.2. Research procedure

Preparation of synthetic struvite

The research stand was composed from the beaker with volume of 500 ml located on a plate of a magnetic mixer and a pH-meter. Solutions were prepared based on distilled water and phosphate salt in the form of KH_2PO_4, ammonium salt in the form of NH_4Cl and magnesium salt in the form of $MgSO_4 \cdot 6\ H_2O$. A constant value of pH = 10 was used, determined based on the literature data. This value represents a point of precipitation of struvite sediment for almost any concentration of ammonium and phosphate ions if adequate amount of magnesium ions is ensured. 1M solution of NaOH was used for correction of pH = 10. The examinations were conducted for PO_4^{3-} ions (50 mg/dm^3, 100 mg/dm^3, 150 mg/dm^3, 200 mg/dm^3 and 250 mg/dm^3) and NH_4^+ ions (100 mg/dm^3, 200 mg/dm^3, 300 mg/dm^3, 400 mg/dm^3, 500 mg/dm^3). Concentrations of Mg^{2+} were 10 mg/dm^3, 20 mg/dm^3 and 30 mg/dm^3. At this stage of the research, the most beneficial proportion of ions was determined, for which the highest struvite mass was obtained. The surface composition of the precipitated sediment was evaluated using the X-ray diffractometer.

Preparation of soil and mixtures of soil and struvite

The air-dry soil used for the examinations was sieved on a sieve with 2 mm mesh. After preparation, the soil was used to obtain mixtures with various doses of struvite:

1) 250 g soil + plants,
2) 250 g soil + 0.1 g struvite + plants,
3) 250 g soil + 0.5 g struvite + plants,
4) 250 g soil + 1.0 g struvite + plants.

Each combination was prepared in five replicates.

Growing mustard in a phytotron chamber

Pots with 250 g and the prepared mixtures were used for the pot experiment. Certified white mustard (*Sinapis alba)* was used as a biomass, with 0.5 g seeds put in the pots with soil and mixtures. The pots with the sown white mustard were placed in the phytotron chamber (P.H.U. Biogenet) for the period of four weeks, during the process the air temperature in the chamber was 21°C and during the night 18°C. In addition, the air humidity ranged between 60-100%. Level and time of exposure – (day and night cycle 16/8) day 6:00-22:00. Intensity of light during the day 40,000 lux. Wetting of the research material – watering 3 times a week. The plants were watered with distilled water in order to avoid introduction of additional components such as mineral salts and other contaminants. After four weeks, the experiment was completed and the obtained biomass was weighed, dried and the dry biomass was again determined. Soil was also dried and subjected to further analysis.

Harvesting of the plants and preparation of soil for analyses

Plants were harvested after 4 weeks of the experiment. The overground biomass was cut at the height of 0.5 cm. It was weighed and next dried at the temperature of 70^{o}C for 48 hours and weighted in order to evaluate biomass growth from each pot (g d.m./pot). Furthermore, the air dry soil material was sieved through the sieve with mesh diameter of 2 mm and next prepared for physical and chemical analyses.

2.3. Physical and chemical analyses of substrates

2.3.1. Struvite

XRD – Bruker D8 Advance X-ray diffractometer was used to examine the precipitated sludge. The X-ray photoelectron spectroscopy (XPS) methodology was employed. The methodology uses the effects of interactions of electrons, photons, ions or neutral particles with atoms of the examined specimen. X-ray photoelectron spectroscopy analyses the electrons that escape from the material being analysed due to irradiation with monochromatic soft X-ray radiation (<8 keV). Kinetic energy of photoelectrons allows for identification of elements and analysis of their binding. Furthermore, photoelectron intensity allows for the evaluation of concentrations of elements and the analysis of contribution of various bindings.

2.3.2. Soil and mixtures of soil and struvite

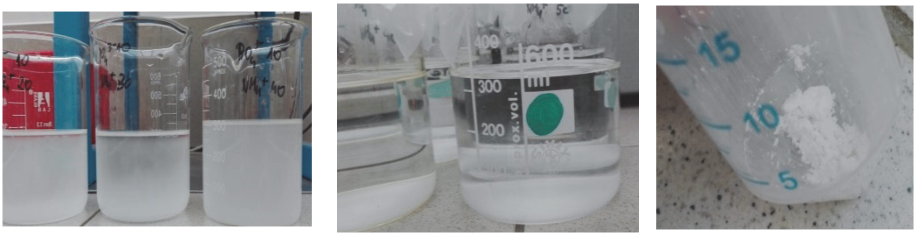
The physicochemical analysis of the substrates was performed according to the methodology developed by Karczewska and Kabała "Methods of Laboratory Analyses of Soil and Plants" (2008). Analyses included: dry mass, content of hygroscopic water, loss on ignition, ash content, reaction, hydrolytic acidity, total alkaline cations, nitrogen content, carbon content, total phosphorus, available phosphorus, heavy metal content.

3. Results of the analysis of research substrates

3.1. Characteristics of substrates: struvite

3.1.1. Amount of precipitated struvite sediment

The experimental design is presented in Fig. 1. Immediate opaqueness was observed for all combinations used after addition of all solutions. However, it took around one hour for the precipitated sediment to be observed on the bottom of beakers. Due to insignificant differences during formation of the sediments for individual concentrations, in order to evaluate the mass of obtained struvite sediments, the samples were centrifuged and left for drying at room temperature and next they were weighed.



Opaqueness of the samples after adding all reaction substrates	Sediment precipitated after 1 hour	Sediments obtained after centrifuging and drying at room temperature

Fig. 1. Stages of precipitation of struvite sediment
Rys. 1. Etapy wytrącania osadów struwitu

Table 1 present the struvite sediments obtained for various combinations of concentration of NH_4^+, PO_4^{3} and Mg^{2+} ions. The results led to the conclusion that the increase in ammonium ions concentration causes a decreasing concentration of magnesium ions necessary for precipitation of struvite, which is consistent with the findings presented by Czajkowska and Siwiec (2011, Czajkowska 2015). The obtained mass of struvite sediments at a specific ion concentration of PO_4^{3-} and NH_4^+, and concentration of ions of Mg^{2+} 10 mg/dm^3 are substantially lower than for Mg^{2+} ion concentration of 20 mg/dm^3. The highest struvite mass (0.338 g) was obtained at concentrations of 500 mg NH_4^+/dm^3, 100 mg PO_4^{3-}/dm^3 and 20 mg Mg^{2+}/dm^3.

Table 1. Amount of struvite precipitated for a given concentration of PO_4^{3-} and NH_4^+ ions, pH=10 and concentration Mg^{2+} ions of 10, 20, 30 mg/dm^3
Tabela 1. Ilość strącanego struwitu dla danego stężenia jonów PO_4^{3-} i NH_4^+ jonów, pH=10 i stężenia jonów Mg^{2+} : 10, 20, 30 mg/dm^3

Concentration ions		PO_4^{3-} [mg/dm^3]				
Mg^{2+} [mg/dm^3]	NH_4^+ [mg/dm^3]	50	100	150	200	250
10	100	0,093	0,109	0,093	0,096	0,099
	200	0,059	0,088	0,105	0,096	0,121
	300	0,055	0,105	0,097	0,101	0,152
	400	0,082	0,098	0,094	0,173	**0,198**
	500	0,069	0,105	0,088	0,099	0,141
20	100	0,140	0,203	0,200	0,198	0,201
	200	0,128	0,215	0,198	0,299	0,202
	300	0,154	0,196	0,194	0,200	0,200
	400	0,169	0,189	0,191	0,205	0,218
	500	0,233	**0,368**	0,281	0,198	0,236
	600	0,122	0,186	0,167	0,184	0,173
	700	0,118	0,180	0,160	0,181	0,165
30	100	-	0,203	-	-	-
	300	-	**0,215**	-	-	-
	500	-	0,196	-	-	-

3.1.2. Analysis of the surface composition of struvite sediments

Fig. 2 shows the results of the analysis of the surface composition of the sediments obtained in laboratory settings from an X-ray diffractometer. The results of the analysis demonstrate that the sediments contain 99% of the mixture of struvite, its amorphous forms and trace contents of compounds used for synthesis of the compound, and NaOH used for correction of pH.

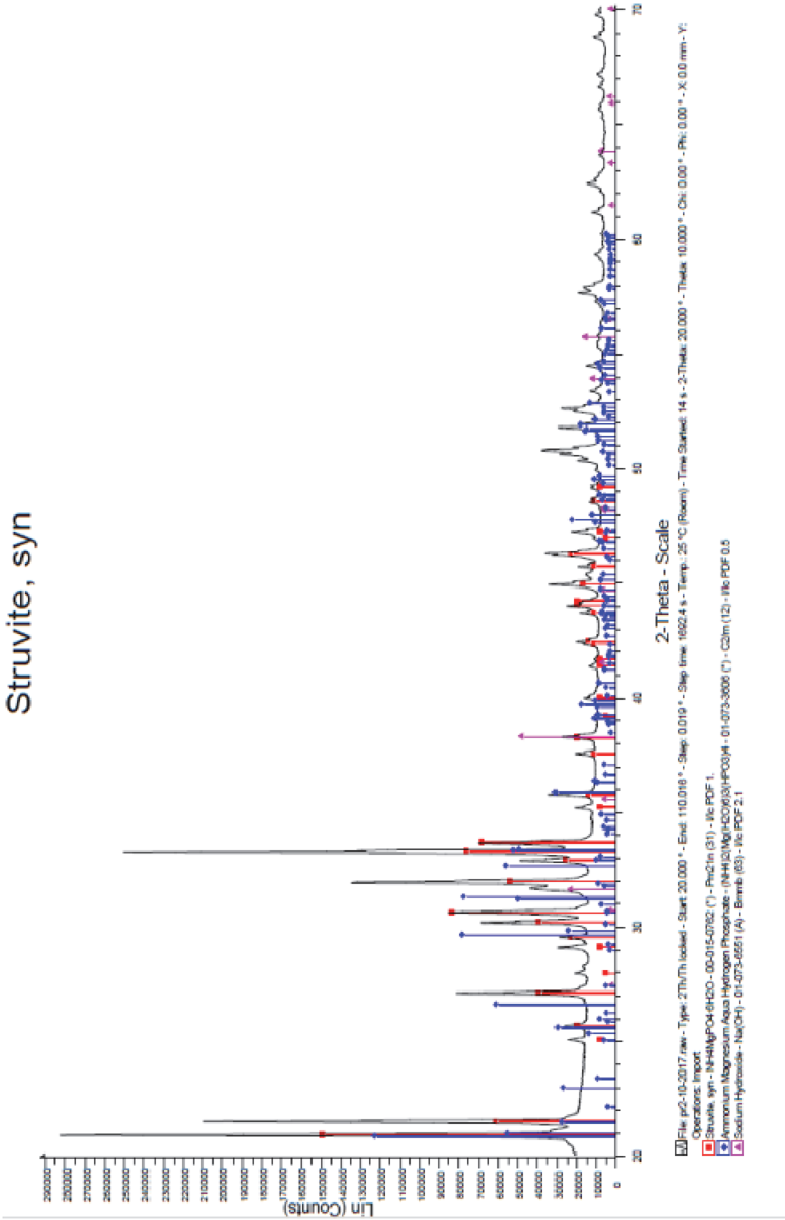


Fig. 2. Results of the analysis of struvite by means of the X-ray diffractometer
Rys. 2. Wyniki analizy osadów struwitu za pomocą dyfraktometru rentgenowskiego

4. Results

4.1. Characteristics of research substrates: soil and soil mixtures

Tables 2 and 3 present an overall characterization of the soil and soil mixtures with various doses of struvite. Percentage of the organic fraction for the soil was 3.44%, whereas for the mixtures, it ranged from 2.29% to 2.36%. All the substrates were characterized by a slightly alkaline reaction. Content of total nitrogen for the soil was ca. 439.2 mg/kg, whereas the contribution of the available forms represented 63%. Total phosphorus content and available forms in the mixtures increased with the increasing struvite percentage. A noticeable increase in the content of available forms of phosphorus (93%) was observed for the mixtures with addition of 0.5g and 1g struvite. The content of total carbon for soil and the mixtures ranged from 1.3% to 1.5%, whereas percentage of total nitrogen was at a low level, from 0.085% to 0.098%. Addition of struvite to soil led to the increase in the content of biogenic elements: total nitrogen and phosphorus, especially in the mixture of soil with 1g struvite.

Table 2. Results of physico-chemical analysis of substrates: soil, mixtures
Tabela 2. Wyniki analizy fizyko-chemicznej substratów: gleba, mieszaniny

Parameters	Soil	Soil + 0.1 g struvite	Soil + 0.5 g struvite	Soil + 1.0 g struvite
Dry matter [%]	0.38	0.69	0.80	0.78
Content of hygroscopic water [%]	99.62	99.31	99.20	99.22
Loss on ignition [%]	3.44	2.29	2.36	2.26
Ash content [%]	96.56	97.71	97.64	97.74

Table 2. cont.
Tabela 2. cd.

Parameters	Soil	Soil + 0.1 g struvite	Soil + 0.5 g struvite	Soil + 1.0 g struvite
pH	H_2O: 7.61 ± 0.049	H_2O: 7.62 ± 0.007	H_2O: 7.73 ± 0.035	H_2O: 7.94 ± 0.014
	KCl: 7.36 ± 0.007	KCl: 7.39 ± 0.007	KCl: 7.40 ± 0.014	KCl: 7.47 ± 0.007
Hydrolytic acidity	pH = 8.29	pH = 8.37	pH = 8.47	pH = 8.72
Total alkaline cations [mmol(+)/100 g]	0.2	0.25	0.2	0.05
Total carbon [mg/g]	13.64 ± 0.09	14.35 ± 0.58	14.28 ± 0.57	14.76 ± 0.76
Total phosphorus [mg/kg]	439.2	463.3	535.7	823.5
Available phosphorus [mg P/kg]	278	305	500	760
Total nitrogen [mg/g]	0.85	0.83	0.86	0.98

The results of the analysis of the content of heavy metals in substrates are shown in Table 5. The results reveal an increase in macro- and microelements in the soil mixtures with struvite compared to pure soil, with particular focus on contents of B, Ca, Cu, K, Fe, Mg, Na and Pb. Three metals were not found: Ag, Cd and Co. Not all the tests revealed presence of As and Cr.

Table 3. Results of the analysis of heavy metals content in substrates of soil and mixtures
Tabela 3. Wyniki analizy zawartości metali ciężkich w podłożach z gleby i mieszanin

Heavy metals content [mg/kg]	Soil	Soil + 0.1 g struvite	Soil + 0.5 g struvite	Soil + 1.0 g struvite
Ag	–	–	–	–
Al	6179.2	6297.2	5698.3	7087.0
As	–	1.177	–	1.162
B	4.792	4.6	4.511	5.61
Ba	45.7	46.2	38.9	50.9
Ca	5812.4	6525.6	5735.1	6074.4
Cd	–	–	–	–
Co	–	–	–	–
Cr	–	11.5	8.49	12.3
Cu	11.7	14.8	12.4	16.6
Fe	6054.4	6138.5	7781.0	7656.1
K	938.8	964.0	834.8	1103.6
Mg	1055.6	1088.3	1130.8	1561.6
Mn	254.5	260.1	235.1	261.6
Na	200.4	177.5	202.6	250.3
Ni	1.561	1.682	1.772	3.217
P	439.2	463.3	535.7	823.5
Pb	40.9	72.8	49.6	55.4
Zn	59.8	63.3	83.4	66.9

4.2. Observation of plant growth

Fig. 3 presents a comparison of seven-day mustard growth for soil and its individual mixtures. It can be observed from the plant size and the number of shooting seeds, that struvite had a positive effect on all samples. At this stage of the research, no significant differences were found for all the plants grown on the mixtures of soil with struvite.

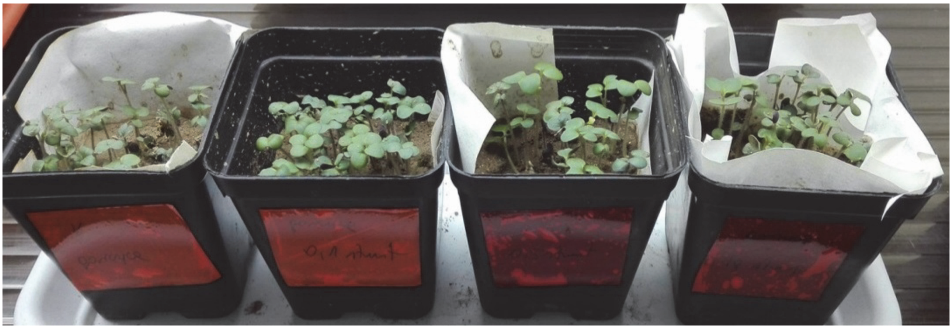


Fig. 3. Comparison of the growth of mustard after 7 days of growing: (from the left) control sample, soil with addition of 0.1 g struvite, soil with addition of 0.5 g struvite, soil with addition of 1.0 g struvite
Rys. 3. Porównanie wzrostu gorczycypo 7 dniach uprawy: (od lewej) próbka kontrolna, gleba z dodatkiem 0,1 g struwitu, gleba z dodatkiem 0,5 g struwitu, gleba z dodatkiem 1,0 g struwitu

Fig. 4 presents a comparison of fourteen-day mustard growth for soil and its individual mixtures. It can be observed that addition of 1.0 g struvite led to the biggest increase in the length of mustard shoots. No significant differences in the length of plants were found in other cases compared to the control sample.

Fig. 4. Comparison of the growth of mustard after 14 days of growing: (from the left) control sample, soil with addition of 0.1 g struvite, soil with addition of 0.5 g struvite, soil with addition of 1.0 g struvite
Rys. 4. Porównanie wzrostu gorczycy po 14 dniach uprawy: (od lewej) próbka kontrolna, gleba z dodatkiem 0,1 g struwitu, gleba z dodatkiem 0,5 g struwitu, gleba z dodatkiem 1,0 g struwitu

The twenty-day growth of mustard is presented in Fig. 5. Comparison of individual samples in terms of mustard shoot length revealed similarities in growing in soil and the soil mixture with addition of 0.1 g struvite. Similarly, no significant differences in the length of mustard plants were observed for the soil mixtures with addition of 0.5 g and 1.0 g struvite. Furthermore, plants grown on the soil with 0.5 g and 1g of struvite were substantially higher than the plants in the control sample and with the dose of struvite of 0.1 g.

Fig. 5. Comparison of the growth of mustard after 21 days of growing: (from the left) control sample, soil with addition of 0.1 g struvite, soil with addition of 0.5 g struvite, soil with addition of 1.0 g struvite
Rys. 5. Porównanie wzrostu gorczycy po 21 dniach uprawy: (od lewej) próbka kontrolna, gleba z dodatkiem 0,1 g struwitu, gleba z dodatkiem 0,5 g struwitu, gleba z dodatkiem 1,0 g struwitu

4.3. Analysis of the plant biomass

Fig. 6 contains the results for plant biomass obtained after 28 days of growing in the phytotron chamber for each combination. The highest value of mean plant biomass and dry mass was obtained for the mixture of soil with 1g struvite. In the case of the mixture of soil with 0.5 g struvite, lower values of the analysed parameters were obtained compared to the control sample. Table 4 presents the results for individual repetitions and the means with standard deviations for each combination.

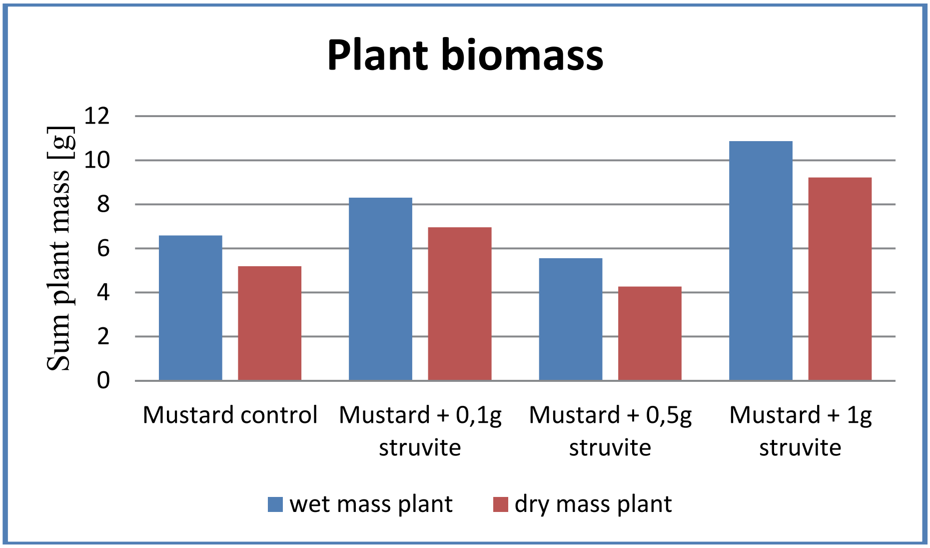


Fig. 6. Comparison of plant biomass
Rys. 6. Porównanie biomasy roślinnej

Table 4. Plant biomass
Tabela 4. Biomasa roślinna

Type of combination	Wet mass plant	Dry mass plant
	Average ± SD	
Mustard control	2.197 ± 1.17	1.730 ± 1.03
Mustard + 0.1 g struvite	2.767 ± 1.34	2.320 ± 1.21
Mustard + 0.5 g struvite	1.853 ± 1.06	1.423 ± 1.15
Mustard + 1.0 g struvite	3.623 ± 1.90	3.073 ± 1.81

4.4. Analysis of the soil after completion of the experiment

Tables 5 and 6 contain the results of the physico-chemical analysis for all combinations (soil and soil mixtures) after 28 days of growing mustard. Similarly to soil and control mixtures, the samples were characterized by a slightly alkaline reaction, with the value of pH ranging from 7.58 to 7.85 in distilled water, whereas these values of KCl ranged from 7.23 to 7.39. The values of pH decreased with increasing struvite dose in the samples. Reaction of soil and mixtures is adequate for growing plants. Hydrolytic acidity for all samples was similar. Availability of nutrients for plants depends on acidity of soil they grow in (Mocek 2015, Zawadzki 1999). Some nutrients in acid soils transform into hardly available forms e.g. molybdenum, boron and phosphorus. Furthermore, the amount of organic matter is reduced in these soils while activity of heavy metals, such as iron, manganese, zinc, copper and lead, and their availability for plants increase (Handzel et al. 2017).

Total organic content increased with the struvite dose in the mixture and was: 15.5 mg/g for soil without additions, 15.34 mg/g for the mixture with the dose of 0.1 g struvite and 16.55 mg/g and 17.88 mg/g for samples with 0.5 and 1.0 g struvite. After completion of the experiment, it was observed that total content of all metals in the soil material declined in all control combinations. The basic factor that impacts on mobility of elements in soil is water, where, depending on the natural or anthropogenic environment, pH and chemical composition are formed (Nowińska & Adamczyk 2013). The increase in pH and content of loamy minerals and organic matter usually improves capacity of soil to absorb heavy metals (Gorlach & Gambuś 1991).

Table 5. Results of physico-chemical analysis of soil: control soil and mixtures (after pot experiment)
Tabela 5. Wyniki analizy fizykochemicznej gleby: kontrola gleby i mieszanin (po doświadczeniu wazonowym)

	Plant control	Plant + 0.1 g struvite	Plant + 0.5 g struvite	Plant + 1.0 g struvite
pH	H_2O: 7.85 ± 0.09	H_2O: 7.66 ± 0.06	H_2O: 7.70 ± 0.03	H_2O: 7.58 ± 0.08
	KCl: 7.39 ± 0.04	KCl: 7.25 ± 0.04	KCl: 7.29 ± 0.03	KCl: 7.23 ± 0.09
Hydrolytic acidity	pH = 8.49	pH = 8.47	pH = 8.49	pH = 8.36
Total alkaline cations [mmol(+)/100 g]	0.2	0.2	0.1	0.2
Total carbon [mg/g]	15.90 ± 0.81	15.34 ± 0.15	16.55 ± 0.32	17.88 ± 0.67

Table 5. cont.
Tabela 5. cd.

	Plant control	Plant + 0.1 g struvite	Plant + 0.5 g struvite	Plant + 1.0 g struvite
Total phosphorus [mg/kg]	415.8	471.0	584.6	688.8
Available phosphorus [mg P/kg]	253	308	490	680
Total nitrogen [mg/g]	0.97	0.91	1.03	1.05

Table 6. Results of heavy metals analysis for soil and mixtures (after pot experiment)
Tabela 6. Wyniki analizy metali ciężkich dla gleby i mieszanin po zakończeniu doświadczenia wazonowego)

Heavy metals content [mg/kg]	Soil	Soil + 0.1 g struvite	Soil + 0.5 g struvite	Soil + 1.0 g struvite
Ag	–	–	–	–
Al	5991.1	6151.0	6269,7	5381.6
As	1.331	1.406	1.304	1.445
B	5.14	5.06	6.73	4.148
Ba	51.5	44.6	48.9	44.2
Ca	5675.1	5073.6	5761.1	7009.8
Cd	–	–	–	–
Co	–	–	–	–
Cr	10.1	9.47	9.5	7.83
Cu	11.1	10.3	12.5	12.1
Fe	5836.2	6225.0	5896.8	5408.8
K	859.0	876.7	893.7	768.3
Mg	1248.3	1051.1	1323.7	1342.5
Mn	222.4	311.2	224.9	227.0

Table 6. cont.
Tabela 6. cd.

Heavy metals content [mg/kg]	Soil	Soil + 0.1 g struvite	Soil + 0.5 g struvite	Soil + 1.0 g struvite
Na	75.4	218.6	90.7	85.4
Ni	1.147	1.886	2.385	2.496
P	415.8	471.0	584.6	688.8
Pb	30.2	30.0	38.8	37.3
Zn	65.7	58.8	61.7	62.4

5. Summary

At the end of the 20th century, a discussion was started among people who are involved in agricultural production concerning technologies of plant nutrition. It was found that previous fertilization method do not meet their role since a barrier of efficiency of the nutrient doses used was already reached. The increasing physical and chemical degradation of soil has led to changes in the physiological status of plants, resulting in the decrease of yield and its quality. First and foremost, one should care for adequate soil status as a basic and the only source of nutrients, water, growth substances for plants.

Soil additions, composed of specific mixtures of mineral compounds, should impact on activation of the processes of cellular metabolism and soil microflora which is best prepared for the environment. Adequate fertilization has a mild effect on processes that occur in humus. This leads to several reactions which are conducive to the development of soil and plants, thus allowing for compensation of the degrading effect of intensive agricultural production.

The research studies were started in order to develop fertilizers rich in microelements, growth regulators or amino acids with extended period of release of biogenic elements (Ciesielczuk et al. 2015, Ciesielczuk et al. 2016). An important factor of using fertilizers is their dose, which is closely related to specific expected soil parameters.

6. Conclusions

The focus of this study was on comparison of the effect of various synthetic struvite doses used as a fertilizer on the growth and biomass of mustard. A pot experiment was conducted in controlled conditions of a phytotron chamber. The analysis of the results obtained in the study leads to the following conclusions:

- It was found that physico-chemical properties of soil such as: pH, acidity, content of biogenic elements (N, P), content of micro- and macroelements improved with the increasing struvite dose.
- Comparison of the length of mustard shoots, grown on the mixtures with struvite leads to the conclusion that the dose of 0.5 g is sufficient for maintaining a maximal length of the plants.
- The highest value of plant biomass (10.87 g) and dry biomass (9.22 g) was obtained for the dose of 1g struvite to soil.
- Based on the results of physicochemical analysis of soil and the obtained biomass, it was found that the most beneficial struvite dose was 1.0 g.
- It should be noted that the most beneficial dose of struvite was considered the largest of the experiments, so in the future the research should be extended with more than 1.0 g doses, also taking into account the extension of the experiment duration to determine the time of action and release of struvite components as a fertilizer.

The research was funded by the project No. BS/MN-401-310/17.

References

Ciesielczuk, T., Rosik-Dulewska, C., Wiśniewska E. (2015). Possibilities of coffee spent ground use as a slow action organo-mineral fertilizer. *Rocznik Ochrona Środowiska, 17*, 422-437.

Ciesielczuk, T., Rosik-Dulewska, C., Szewczyk, A., Poluszyńska J. (2016). Dynamic of Nitrogen Leachate from Slow-action Fertilizers in a Laboratory Experiment. *Rocznik Ochrona Środowiska, 18*, 506-517.

Czajkowska, J., Siwiec, T. (2011). Crystallization of struvite from synthetic wastewater in an experimental installation in flow conditions, *Engineering and Environmental Sciences, 52*, 130-139.

Czajkowska, J. (2015). Conditions for precipitating sediments with struvite content, Summary of the doctoral dissertation, University of Zielona Góra, Faculty of Civil Engineering, Architecture and Environmental Engineering, Institute of Environmental Engineering, Zielona Góra 2015.

Faucon, M., Houben, D., Reynoird, J.P., Dulaurent- Mercadal, A.M., Armand, R., Lambers, H. (2015). Advances and Perspectives to Improve the Phosphorus Availability in Cropping Systems for Agroecological Phosphorus Management, Advances in Agronomy,134, 51-79.

Gorazda, K., Wzorek, Z., Jodko, M., Nowak, A.K. (2004). Struvite- physicochemical properties and application, *Science Technology Monthly Chemik, 57(1)*, 9-13.

Gorlach, E., Gambuś, F. (1991). Desorption and Phytotoxicity of Heavy Metals Dependent on Soil Properties, Yearbooks of Tuberculosis T. Xui, 3/4, Warsaw, 207-214.

Handzel, A., Królczyk, J.B., Latawiec, A.E., Pluta, K., Malina, D., Sobczak-Kupiec, A. (2017). Analysis of physicochemical properties of soils and determination of selected elements, Infrastructure and Ecology of Rural Areas - Infrastructure And Ecology of Rural Areas, POLISH ACADEMY OF SCIENCES, Branch in Cracow, *Technical Committee of Rural Infrastructure, I(2)*, 419-432.

Hudziak G., Gorazda K., Wzorek Z. (2012). Main directions in the application of ashes after thermal treatment of sewage sludge. Technical Transactions. Chemistry, Technical Journal, *Chemistry, 16*, 41-50.

Jodko M., Kowalski Z., Wzorek Z., The method of thermal utilization of sludges with a high content of iron compounds from urban wastewater treatment, Patent Office of the Republic of Poland, 2003.

Karczewska, A., Kabała, C. (2008). Method of laboratory analysis of soils about plants, Wroclaw, http://www.ar.wroc.pl/~kabala.

Mocek, A. (2015). Soil science, PWN Scientific Publisher.

Nowińska, K., Adamczyk, Z. (2013). Mobility of Elements Accompanying Waste in Zinc and Lead Metallurgy in the Environment, *Mining and Geology, 8*, 77-87.

Worwąg, M., Mędrala, M. (2017). *Book of Abstracts, International Conference of Environmental Biotechnology,* Czestochowa University of Technology, Faculty of Infrastructure and Environment, Institute of Environmental Engineering, 12.12.2017. 26.

Wzorek, Z. (2008). Reclamation of phosphorus compounds from thermally processed wastes and their use and their use as a substitute for natural phosphoric raw materials, *Series of engineering and chemical technology, Cracow, 11(14-15)*, 25-28.

Wzorek, Z. (2008a). Alternative phosphorus raw materials, publishing house of the Cracow University of Technology, Cracow.
Zawadzki, S. (red). (1999). Soil science, PWRiL, Warsaw, 467-470.

Ocena wpływu struwitu na wzrost gorczycy *Sinapis alba*

Streszczenie

Struwit to uwodniony fosforan amonowo-magnezowy o wzorze chemicznym $MgNH_4PO_4 \cdot 6H_2O$,odkryty w 1845 roku. Minerał charakteryzuje się barwą przejrzysta/półprzejrzysta biała o szklistym połysku, twardością według skali Mohsa wynoszącą 2, masą właściwą 1700 $kg \cdot m^{-3}$. Jego krystaliczna forma tworzy się przy odpowiednich stężeniach jonów magnezowych, fosforanowych oraz amonowych. W środowisku naturalnym jego obecność stwierdzono głównie w rozkładające się materii organicznej. Jednak kryształy struwitu mogą się także tworzyć na oprzyrządowaniu instalacji do oczyszczania ścieków (w rurociągach, wirnikach pomp itp.). Odbywa się w to sposób niekontrolowany i niesie za sobą problemy techniczne w oczyszczalni. Najczęstsze występowanie stwierdzono w osadach ściekowych po oczyszczaniu metodami biologicznymi oraz osadach ściekowych pochodzenia zwierzęcego po fermentacji beztlenowej. Jednak z racji tego, że dany związek stanowi źródło fosforu, zauważono możliwość wykorzystania struwitu w celach nawozowych. Jako granulat nawozowy ma niską rozpuszczalność przez co uważany jest za bardziej przyjazny środowisku. Wolno rozpuszcza się w glebie co powoduje, że rośliny same mogą dozować jaką jego ilość pobiorą z otoczenia. Technologie odzysku tego minerału nie są jednak jeszcze powszechnie stosowane ponieważ są wymagające pod względem ekonomicznym. Nad struwitem prowadzone są ciągle intensywne badania mające na celu zoptymalizowanie jego procesu wytrącania.

Niniejsza praca skupiała się na porównaniu wpływu różnych dawek (0,1; 0,5; 1,0 g/250 g gleby) struwitu syntetycznego zastosowanego jako nawozu na wzrost oraz biomasę gorczycy. Doświadczenie, miało charakter wazonowy i było prowadzone w kontrolowanych warunkach komory fitotronowej. Stwierdzono, że właściwości fizycznochemiczne gleby takie jak: pH, kwasowość, zawartość pierwiastków biogennych (N, P), zawartość makro i mikroelementów; poprawiały się wraz z wzrastającą dawką struwitu. Na podstawie uzyskanych wyników dla poszczególnych kombinacji, stwierdzono, że dawka 0,5 g jest wystarczająca, do uzyskania maksymalnej długości plonów. Jednakże, nie korelowało to z uzyskaną świeżą oraz suchą biomasą, gdzie najwyższą wartość (10,87 g dla świeżej biomasy oraz 9,22 g dla suchej biomasy) uzyskano dla dawki 1,0 g struwitu.

Abstract

Struvite is a hydrated ammonium magnesium phosphate of chemical formula $MgNH_4PO_4 \cdot 6\ H_2O$, discovered in 1845. Mineral is characterized by a transparent / translucent white color with a glossy gloss, a Mohs hardness of 2, a specific weight of 1700 $kg \cdot m^{-3}$. Its crystalline form is formed at appropriate concentrations of magnesium, phosphate and ammonium. In the natural environment its presence was mainly found in decomposing organic matter. However, struvite crystals may also be formed on the equipment of sewage treatment plants (piping, pump impellers, etc.). This is done in an uncontrolled manner and carries with it technical problems in the treatment plant. The most frequent occurrence was found in sewage sludge after biological treatment and sewage sludge of animal origin after anaerobic digestion. However, due to the fact that a given compound is a source of phosphorus, the possibility of using struvite for fertilization has been noted. As the fertilizer granule has low solubility, it is considered to be more environmentally friendly. It slowly dissolves in the soil, which causes the plants themselves to dispense the amount that they take from the environment. The recovery technologies of this mineral are not yet widely used because they are economically demanding. There are still intensive researches on the struvite to optimize its precipitation process.

This work focuses on comparing the effects of different doses (0.1, 0.5, 1.0 g/250 g of soil) of a synthetic struvite used as a fertilizer for growth and biomass of *Sinapis alba*. The experiment was vase-shaped and was carried out under controlled conditions of the phytotron chamber. It was found that the physical physico-chemical properties of soil such as: pH, acidity, content of biogenic elements (N, P), content of macro and microelements; they improved with the increasing dose of struvite. Based on the results obtained for each combination, it was found that a dose of 0.5 g is sufficient to obtain the maximum yield length. However, this did not correlate with the obtained fresh and dry biomass, where the highest value (10.87 g for fresh biomass and 9.22 g for dry biomass) was obtained for a dose of 1.0 g of struvite.

Słowa kluczowe:
struwit, nawozy mineralne, biomasa roślinna, gleba, nawożenie

Keywords:
struvite, mineral fertilizers, plant biomass, soil, fertilization