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CHAPTER VIII

Szejniuk Bożena[1], Wasilewski Piotr[2], Budzińska Katarzyna[1],
Gałęzewska Beata[1], Kubisz Łukasz[1]

EFFECT OF COMPOST FROM SEWAGE SLUDGE ON PLANT DEVELOPMENT

Introduction

Natural use of sewage sludge is in accordance with the policy of the European Union, which approves of introduction into soils components accumulated in bio-wastes, on condition of meeting the requirements contained in Directives concerning protection of the environment and soil against contamination (GWOREK et al. 2002). Issues related to the processing and management of sewage sludge are essential in the present time, given an increase in the number of sewage treatment plants established in Poland and the necessity of meeting the requirements connected to the standards concerning environmental protection. Moreover, a constant growth in the number of new sewage treatment plants contributes to formation of considerable amounts of sludge which poses a serious problem. Its composition depends on the type and origin of sewage and the technology of treatment (WŁODEK 2007). Sludge formed in biological treatment plants usually has the content of organic substance and nutrients which is favourable for plants (MAZUR 1996), thus it can be applied for natural management.

The direction of sewage sludge processing depends on physico-chemical and sanitary and hygienic properties. The excessive content of heavy metals is the factor that decidedly limits sewage sludge application in the natural environment (HOODA, ALLOWAY 1996, PALES et al. 1996). In the order of the Ministry of the Environment of 1 August 2002 on municipal sewage sludge, the content of heavy metals and their load introduced into the environment is assumed as one of the basic criteria for its agricultural use. Exceeding the standard level of even one of all the list of heavy metals disqualifies such material from the natural use. In the case of sewage sludge generated in treatment plants handling the areas producing no industrial wastes most often there is a possibility of their processing, after initial processes of thickening and stabilization, into composts which find application to soil fertilization. Application of compost for protection of soil structure and an increase in nutrient availability exerts a favourable effect on the state of the environment (JAKOBSEN 1995].

Compost from sewage sludge applied as a fertilizer has favourable soil-forming properties; organic substances from compost remain in soil for a longer time, which determines the improvement of the water and gas relations of soil and leads to an increase in fertility indexes (CORTELLINI et al. 1996; SZEJNIUK 2005). Due to its manurial properties, the compost obtained from municipal sewage sludges which meets quality standards shows the effect similar to that of organic fertilizers which are applied traditionally, and is an effective source of N, P and K utilized by plants (WARMAN, TERMEER 2005). The correct effect of a compost on the soil environment is determined by its proper chemical composition (JAKOBSEN 1995). According to GONDEK and FILIPEK-MAZUR (2006), analyzing the effect of compost application on soil properties and the availability of some microelements under the influence of those additives, they indicated a series of far-reaching positive changes in soil, preparing this organic fertilizer for retaining or restoring fertility of agricultural soils. Using compost as an organic fertilizer constitutes the optimal method which allows the complete utilization of the physical and chemical properties of this material for regeneration, fertilization and recovering of the most essential bio-components of soil.

Favourable effect of compost is observed among others in its deacidifying activity, a decrease in hydrolytic acidity, a growth of the contents of calcium, carbon and organic nitrogen and a considerable increase in proportion of bio-available forms of microelements (WARMAN, TERMEER 2005). Composts made with an addition of rural wastes and straw constitute a valuable organic fertilizer rich in nutrients (particularly in nitrogen and phosphorus). The effect of such a fertilizer on plants is slower, since nitrogen compounds occur in it in humus combinations. In this way, it can exert a favourable effect for several years, as opposed to mineral fertilization, particularly with nitrogen and potassium (CZYŻYK et al. 2002). Forming the fertility and yielding potential of soils is a long-lived process, and changes in physico-chemical properties, both favourable and unfavourable, are clearly noticeable only in long-term experiments. In consequence, the full spectrum of modifying effect of composts on soil physico-chemical properties is possible to observe and assess as a whole in studies conducted over a period of several years (GONDEK, FILIPEK-MAZUR 2005; GONDEK, FILIPEK-MAZUR 2006).

Introducing moderate amounts of compost into soils resulted in improving its composition, especially when the compost was applied to the surface of the soil and after sowing the cultivated crops. The soil surface was in this way protected against the negative impact of rainfall and fast drying at a later time. Under these conditions, also water soaked through soil much faster, also after the application of a thin layer of compost (JAKOBSEN 1995). In agricultural practice, spreading of manurial activity in time can be treated as a undeniable asset of this fertilizing material, which due to its non-invasive effect on soil and by means of an increase in sorption capacity improves the structure and increases the water capacity of soils, and exerts a slight influence on the chemical composition of generated effluents which, in turn, directly translates into water environment safety (CZYŻYK, KOZDRAŚ 2003).

In Poland, the trade standard BN-89/9103-09 for composts from mixed wastes, including composts produced from sewage sludges or with an addition of sewage sludge, was in effect for many years, which contained requirements concerning macroelements, heavy metal concentration, proportion of glass, ceramics and stones, as well as sanitary and hygienic features. After coming into force of the act on fertilizers and fertilization, the entities launching fertilizers produced on the basis of organic substances need an appropriate permission given by the Minister of Agriculture. The order of 19 October 2004 concerning the execution of provisions of the act on fertilizers and fertilization defines the scope of research and requirements concerning the opinions which make it possible to give a permit for launching such a fertilizer.

A favourable impact of various composts which provide the source of available nutrients on an increase in plant yield is emphasized in the literature (EPSTEIN 1997, AGGELIDES, BERNAL et al. 1998, LONDRA 2000, MARINARI et al. 2000). It has been indicated that some plants cultivated on soils enriched with compost show varied growth dynamics (KORBOULEWSKY et al. 2002). Positive effect of compost from municipal sewage sludge meeting requirements concerning quality depends on keeping the appropriate proportions during soil fertilization. Composts made from sewage sludges exert an influence on the content of potassium, calcium and magnesium in agricultural crops, which is determined by the type and rate of compost (CIEĆKO, HARNISZ 2002).

Factors of the study

In order to indicate the effect of compost on the growth of selected agricultural crops, an experiment was carried out during two growing seasons in 2005 and 2006. The one-factorial pot experiment was established in the complete random design in which emergence, growth and green matter yield of plants cultivated on different substrates were evaluated. Pots of a volume of 11 litres and an area of 0.0615 m^2 were filled with soil of class IVb collected from the topsoil, into which an addition of compost from sewage sludge was introduced according to the following scheme:
P0 – soil without an addition of compost – the control
P1 – soil + compost in a ratio of 3 : 1
P2 – soil + compost in a ratio of 6 : 1
P3 – soil + compost in a ratio of 9 : 1

Compost from sewage sludge applied in the experiment was made from activated sludge with a dry matter content of 24%, subjected to the process of dehydration by means of the ANDRITZ press. Sewage sludge was mixed with wood chips and burnt lime in a ratio of 1: 0.3 : 0.01. Composted material was placed in a revolving bioreactor for 5 days and then subjected to maturation in heaps until the moment of obtaining compost stability. The compost obtained was characterized by a high content of phosphorus (0.56% d.m.) and potassium (0.30% d.m.), essential for its manurial value. In addition, this fertilizer had a favourable alkaline reaction (pH 8.2), exhibiting deacidifying effect on soil. Relatively low content of organic substance (25.86% d.m.) and organic nitrogen (0.47% d.m.) was found, strongly correlated with the manurial value of the tested material. Physico-chemical analysis confirmed that the examined parameters of the compost was in accordance with the quality standards contained in the Regulation of the Ministry of Agriculture and Rural Development of 19 October 2004 on executing some regulations of the act of fertilizers and fertilization [Dz. U. No. 236 item 2369]. The level of the heavy metals determined (Cr, Zn, Cd, Cu, Pb) was appropriate from the point of view of environmental protection and corresponded to the standards required for composts applied as fertilizers.

Prepared substrates with different proportions of compost were seeded as follows: yellow and blue lupines (13 germinating seeds per pot), oats (62 germinating seeds per pot) and spring rye (55 germinating seeds per pot). After sowing, until the time of full emergence, the pots were covered with a net in order to protect them against birds. After 14 days from sowing, the assessment of emergence was carried out by means of counting the number of plants grown in each pot. Observations of the appearance of plants in the pots were conducted at two-week intervals, and deformations, discolorations, the occurrence of diseases and pests were recorded. In dry periods during the growth the plants in pots were watered in order to obtain a substrate moisture at a level of 60% field water capacity. Water volume was changeable depending on its transpiration through the plants during their growth. Directly before harvesting, the average plant height of a given species in the sample was determined (oats and spring rye – average height of 10 plants of a given species), as well as the amount of plants of a given species in the sample. After reaching harvesting maturity by the plants, they were harvested, and biometric measurements and statistical calculations were carried out. Results of study were subjected to statistical analysis in the completely random design. Significance of differences between the averages was determined by means of Tukey's test.

Responses of chosen agricultural crops to addition of compost to soil substrates

Growing deficit of humus substances in soils that occurs in Poland resulted in a distinct growth of initiatives aiming at looking for new sources of organic matter, which could be applied safely as alternative fertilizers. According to MAZUR (1999), this idea is supported by the confidence that ecological balance can be retained or restored, among others, by means of proper conditions of generated waste utilization, which is becoming more and more apparent to the society. Correct application of compost in order to optimize yielding conditions and to provide the nutritional and technological quality of yield requires thorough knowledge of responses of selected agricultural crops cultivated on soils supplied with this fertilizer. The experiment aiming at indicating the effect of compost addition to soil was carried out in two growing seasons and it showed a distinct influence of the addition of compost from sewage sludge to soil on the emergence of legumes and cereals. According to the data presented in Table 1, emergences of the tested plant species were in most cases significantly diversified by the addition of compost to the substrate.

Table 1

Effect of varied addition of compost on emergence (plants x pot^{-1}) of plants

Substrate	2005				2006			
	Yellow lupine	Blue lupine	Oats	Spring rye	Yellow lupine	Blue lupine	Oats	Spring rye
P0	9.0	12.7	45.7	50.0	11.0	9.0	60.3	46.3
P1	3.7	8.0	32.3	37.0	0.3	3.3	56.7	40.3
P2	8.3	8.0	34.7	36.3	3.7	6.7	55.0	39.0
P3	9.3	10.7	51.3	49.7	10.3	8.0	56.0	49.3
Average	7.6	9.8	41.0	43.2	8.3	6.8	57.0	43.8
$LSD_{p=0.05}$	1.5	1.7	8.7	7.9	4.3	n.s.	n.s.	9.0

n.s. – differences not significant

Yellow and blue lupines responded negatively to an addition of compost to soil, since in all the cases in 2005 and 2006 a decrease in the number of legumes emerging was observed at higher compost rates. A difference between water potential in the soil solution and that in seeds has a decisive impact on water absorption during swelling of seeds. An increase in compost proportion in the substrate probably resulted in a growth of soil solution concentration, which along with high demand of lupine seeds for water in the course of swelling (the amount of water absorbed in lupines amounts to 170% of seed mass, and in cereals 60 – 80%) caused the worsening of their emergence (GRZESIUK, KULKA 1981, JASIŃSKA, KOTECKI 1999). Similar results of a study was presented by LEKAN and KACPEREK (1990), who found, on the basis of the long-term experiments carried out with the use of compost from municipal wastes, that an addition of compost inhibited plant germination and emergence.

FILIPEK-MAZUR AND GONDEK (2003) report that an unfavourable effect of compost observed in the first year after its application decreases in successive years of the study. Slightly different opinion is presented by CZYŻYK et al. (2002), who report that varied rates of compost applied by them did not have a significant effect on plant emergence, which was uniform in all the combinations of the experiment. The results obtained from the experiment are confirmed by an earlier study by SZEJNIUK et al. (2005), where using similar methods, the weakest plant emergence was also observed at a higher rate of compost. In the results of the present study (Table 1) in cereal plants, the loss of oats and spring rye at the initial stage of growth remained at a low level as compared with legumes. WINIARSKA and LEKAN [1991) report that the diversification of plant responses to an addition of compost to soil might be related to individual abilities of particular plants to utilize nutrients taken up from organic fertilizers.

The height of plants depended on the substrate on which they were growing. From the data (Table 2) it follows that yellow lupine in 2005 clearly negatively responded to an addition of compost to soil, decreasing the height of shoots by as much as 1/3 at the lowest rate applied. Further addition of organic material did not result in the intensity of shoot reduction in this species. Also blue lupine indicated a decrease in shoot height after fertilization with compost, yet such a response was proved between the control and treatments with P2 and P1. Significant statistic difference in the height of plants fertilized with compost was found in 2006 in oats and blue lupine cultivation (Table 2). In the case of oats, the greatest plant height was observed on treatments P2 with an addition of compost in a ratio of 6:1, where the height was larger on average by 29%, as compared with the plants on the control substrate P0. Significant differences in the height of oats were found between the plants coming from pots filled with soil only (P0) and the plants from the treatments P2 and P3.

Table 2

Effect of varied addition of compost on plant height (cm)

Substrate	2005				2006			
	Yellow lupine	Blue lupine	Oats	Spring rye	Yellow lupine	Blue lupine	Oats	Spring rye
P0	27.2	23.1	54.8	73.7	46.4	47.1	41.6	58.7
P1	18.9	16.5	57.3	64.3	n.d.	30.7	50.7	62.7
P2	18.6	18.1	65.2	59.8	51.0	29.6	53.8	64.0
P3	18.3	20.4	50.3	60.1	41.4	40.6	51.1	63.4
Average	20.7	19.5	56.9	64.5	46.3	37.6	49.3	62.4
$LSD_{p=0.05}$	8.4	4.5	n.s.	6.8	n.s.	17.4	9.4	n.s.

n.d. – no data; n.s. – differences not significant

Results similar to those described above were obtained by PARADYSZ (2001), who in his study indicated a favourable effect of compost on the growth and size of plants. This author, however, emphasizes that stimulating effect of the addition of compost was caused by improvement of soil properties, such as aeration and retaining of moisture.

By contrast with the conclusions formulated by this author, however, in the own pot study an addition of compost to soil in the cultivation of blue lupine caused a decrease in plant height in all the experimental variants. The smallest height of blue lupine in 2006 was observed on treatments P2 and it was significantly smaller as compared with the value of the tested character on the control treatments (by 37%).

Different response of cereal crops and legumes to an addition of compost to soil might result from individual needs of those plants in respect of the contents of particular nutrients in the soil substrate and different preferences concerning conditions of the soil environment, especially in terms of the presence of the bacteria *Rhizobium* living in symbiosis with lupines (SZEMBER 2001).

Effect of compost on tested plant yield

Poor emergence of plants had an unfavourable effect on the green forage yield of the tested plant species. In both growing seasons, lupines yielded significantly the best on the substrate without an addition of compost (Table 3). A decrease in green forage yield depending on the year of the study and the substrate was 37.1% - 63.9% for yellow lupine and 32.3% - 94.3% for blue lupine. Yielding of cereal plants on substrates with an addition of compost was the absolute opposite to the response of lupines, as green matter yields of those plants were statistically significantly higher and grew proportionally along with the growth of the amount of compost added to the substrate.

Table 3

Effect of varied addition of compost on yield (g x pot^{-1}) of green mass of tested plants

Substrate	2005				2006			
	Yellow lupine	Blue lupine	Oats	Spring rye	Yellow lupine	Blue lupine	Oats	Spring rye
P0	36.9	30.6	58.9	26.4	72.5	51.4	57.3	37.3
P1	23.2	20.7	80.1	47.5	0.0	2.9	92.0	67.2
P2	28.3	24.5	89.1	48.5	26.2	16.5	98.7	70.0
P3	28.7	29.6	129.6	67.2	57.0	32.4	73.9	54.1
Average	29.3	26.4	89.4	47.4	51.9	25.8	80.5	57.1
$LSD_{p=0.05}$	5.6	4.9	31.1	20.7	40.4	12.9	25.1	9.5

Similar tendencies were observed in a study of the effect of an addition of compost from municipal wastes on the yield of rye green matter in pot experiments. It was found that winter rye yield increased proportionally to the growth of an addition of compost into podzolic soil and loose sand only up to a level of 2%, whereas above this limit a decrease in plant yield occurred (SZEJNIUK 1997]. Pot experiments carried out by CZYŻYK et al. (2002) confirm the favourable effect of compost from sewage sludge and straw on maize yield, since it was observed that the application of the highest rates of compost resulted in proportional growth in yield of this plant. Mustard, in turn, which was the next plant tested, responded positively to fertilization with mineral nitrogen, whereas an addition of compost did not affect diversification of yields according to the rate size. According to KORBOULEWSKY et al. (2002), plants grown on soil substrates enriched with compost showed various growth dynamics, yet a general, evident, favourable response occurred, resulting in an increase in the biomass of the tested plants grown on soils with an addition of compost.

It follows from Table 3 that the yield of rye green matter also showed an upward tendency in 2005 and 2006 in response to an addition of compost into the soil substrate. FILIPEK-MAZUR and GONDEK (2003) report that the comparable yield of oat dry matter was obtained after fertilization with farmyard manure and compost. Moreover, it was proved that the manurial activity of composts is even better than that of farmyard manure (GONDEK, FILIPEK-MAZUR 2005). Similarly, KOCH et al. (1997), in a study of the effect of sewage sludge and composts obtained from it on the cultivation of selected crops under field conditions, proved that considerable differences occurred in the yield height of the tested plants, which argues in favour of crops coming from plots fertilized with sludges and compost. BARAN et al. (1993a), in turn, found higher plant yields on a soil fertilized with sewage sludge. In that case, they recorded an increase in the content of total carbon and a fraction of humins, contributing to a better availability of accessible nutrients. Favourable effect of sewage sludge was found already at a low level of fertilization from 1 to 5% in relation to the control groups (BARAN 1993b).

Summing up the obtained results presented in this study, it might be concluded that the application of compost from sewage sludge has the most favourable effect on the development of spring rye and oats.

Summary

Composting is one of methods for the natural utilization of sewage sludge. Increasing number of sewage treated and biodegradable waste deposition at landfill sites results in a growing interest in this way of management of wastes from sewage treatment plants. Sewage sludge can be a valuable fertilizer which is possible to be applied in agriculture, on condition that the processes of its initial processing and sanitization will be carried out properly. Compost produced from sewage sludge should be constantly monitored in order to eliminate the hazard of pathogenic microorganisms.

The present study confirms the possibility of applying composts from sewage sludge as fertilizers on soils of low fertility (classes IVb-VI). It also indicates different responses of the plants – particularly legumes – to an addition of compost to the soil or substrate. Therefore, further studies are necessary concerning the plant response to an addition of compost from sewage sludge to soils or substrates. Moreover, action should be taken aiming at showing farmers that these composts can be as safe and effective in increasing the height and quality of yield as the traditional organic fertilizers – farmyard manure, straw and other green manures. The study indicated that the compost from sewage sludge used in the experiments contributed to an increase in green matter yield of oats and spring rye, which proves its considerable usefulness for soil fertilization in cereal crop cultivation.

References

AGGELIDES S.M., LONDRA P.A. 2000: *Effect of compost produced from town waste and sewage sludge on the physical properties of a loamy and a clay soil.* Bioresource Technology, 71: 253-259.

BARAN S., FLIS-BUJAK M., TURSKI R., ŻUKOWSKA G. 1993A: *Przemiany substancji organicznej w glebie lekkiej użyźnionej osadem ściekowym.* Zesz. Probl. Post. Nauk. Rol. 409: 59-63.

BARAN S., TURSKI R., FLIS-BUJAK M., KWIECIEŃ J., MARTYN W. 1993B: *Wpływ uprawy roślin w zmianowaniu i monokulturze na wybrane właściwości gleby lekkiej użyźnionej osadem ściekowym.* Zesz. Probl. Post. Nauk. Rol. 409: 51-58.

BERNAL M.P., PAREDES C., SANCHEZ-MONEDERO M.A., CEGARRA J. 1998: *Maturity and stability parameters of compost prepared with a wide range of organic wastes.* Bioreseurce Technology, 63: 91-99.

CIEĆKO Z., HARNISZ M. 2002: *Wpływ kompostów z osadów ściekowych na zawartość potasu, wapnia i magnezu w wybranych roślinach wprawnych.* Zesz. Probl. Post. Nauk Roln., 484: 77-86.

CORTELLINI L., TODERI G., BALDONI G., NASSISI A. 1996: *Effects on the content of organic matter, nitrogen, phosphorus and heavy metals in soil and plants after application of compost and sewage sludge.* The science of composting: Part 1, ed. Marco de Bertoldi: 457-768.

CZYŻYK F., KOZDRAŚ M. 2003: *Wpływ nawożenia traw kompostem z osadów ściekowych na skład chemiczny odcieków z gleby*. Zesz. Prob. Post. Nauk Rol.: 494, 85-92.

CZYŻYK F., KOZDRAŚ M., SIERADZKI T. 2002: Wartość nawozowa kompostów z osadów ściekowych i słomy. Zesz. Probl. Post. Nauk Roln., 484: 117–124.

EPSTEIN, E. 1997. *The Science of Composting.* Technomic Publishing Co., Lancaster- Basel.

FILIPEK-MAZUR B., GONDEK K. 2003: *Wartość nawozowa kompostu z odpadków zielonych. Krakowa.* Zesz. Probl. Post. Nauk Roln., 494: 113–121.

GONDEK K., FILIPEK-MAZUR B. 2005: *Agrochemiczna ocena wartości nawozowej kompostów różnego pochodzenia.* Act. Agrophys., 5, 2: 271-282.

GONDEK K., FILIPEK-MAZUR B. 2006: *Selected soil properties and availability of some microelements from soil with compost supplement.* Polish J. Soil Sci., 39, 1: 81-90.

GRZESIUK S., KULKA K. 1981: Fizjologia i biochemia nasion. PWRiL Warszawa.

GWOREK B. KLIMCZAK K. GIERCUSZKIEWICZ-BAJTLIK M. 2002: *Aspekty ochrony środowiska w uregulowaniach prawnych dotyczących gospodarki nawozowej i nawożenia w Polsce i Unii Europejskiej.* Zesz. Probl. Post. Nauk Rol. 484, 1: 193-202.

HOODA, P.S., ALLOWAY, B.J. 1996: *The effect of liming on heavy metal concentrations in wheat, carrots and spinach grown on previously sludge applied soils.* J. Agr. Sci., 127: 289-294.

JAKOBSEN S.T. 1995: *Aerobic decomposition of organic wastes 2.Value of compost as a fertilizer.* Resources, Conservation and Recycling 13: 57-71.

JASIŃSKA Z., KOTECKI A. 1999: Łubin. W: Szczegółowa uprawa roślin T2. Wyd. AR Wrocław.

KORBOULEWSKY N., BONIN G., MASSIANI C. 2002: *Biological and ecophysiological reactions of white rocket (Diplotaxis erucoides L) grown on sewage sludge compost.* Environmental Pollution 117: 365-370.

LEKAN S., KACPEREK K. 1990. *Ocena wartości nawozowej kompostu z odpadów miejskich „Dano" w doświadczeniu wazonowym.* Pam. Puł. 97: 187–200.

MARINARI S., MASCIANDARO G., CECCANTI B., GREGO S. 2000: *Influence of organic and mineral fertilizers on soil biological properties.* Bioresource Technol. 72: 9-17.

MAZUR T. 1996: *Rozważania o wartości nawozowej osadów ściekowych*. Zesz. Probl. Post. Nauk Roln. 437: 11-13.

NORMA BRANŻOWA BN-89/99103-09. *Unieszkodliwianie odpadów miejskich (kompost z odpadów miejskich).*

PALES J.D., BREWER S.R., BARETT G.W. 1996: *Metal uptake by agricultural plant species grown in sludge-amended soil following ecosystem restoration practices*. Bull. Environ. Contam. Toxicol., 57, 6: 917-923.

PARADYSZ W. 2001: *Kompostowanie odpadów - dobry interes czy uciążliwa konieczność?* Wyd. Tow. na Rzecz Ziemi, Warszawa.

ROZPORZĄDZENIE MINISTRA ROLNICTWA I ROZWOJU WSI z dnia 19 października 2004 r. w sprawie wykonania niektórych przepisów ustawy o nawozach i nawożeniu. Dz. U. Nr 236 poz. 2369.

ROZPORZĄDZENIE MINISTRA ŚRODOWISKA z dnia 1 sierpnia 2002 r. w sprawie komunalnych osadów ściekowych Dz.U. 2002.134.1140.

SZEJNIUK B. 1997: *Wpływ kompostu uzyskanego metodą „Dano" z odpadów komunalnych na plony żyta w doświadczeniu wazonowym.* Ekol. i Techn. 6, 30: 25–27.

SZEJNIUK B. 2005: *Sanitarno-higieniczne aspekty kompostowania odpadów.* Wyd. ATR Bydgoszcz.

SZEJNIUK B., WASILEWSKI P., BUDZIŃSKA K. 2005: *Wpływ kompostowanych osadów ściekowych i odpadów interwencyjnych na wzrost i plonowanie wybranych roślin uprawnych.* Zesz. Probl. Post. Nauk Roln., 506: 471 – 478.

SZEMBER A. 2001: *Zarys mikrobiologii rolniczej.* Wyd. AR Lublin.

USTAWA z dnia 26 lipca o nawozach i nawożeniu. Dz. U. Nr 89, poz. 991, 2000.

WARMAN P.R., TERMEER W.C. 2005: *Evaluation of sewage sludge, septic waste and sludge compost applications to corn and forage: yields and N, P and K content to crops and soils.* Bioresource Technology 96: 955-961.

WINIARSKA Z., LEKAN S. 1991: *Wpływ kompostu z odpadów miejskich na plonowanie roślin i właściwości gleby w doświadczeniu polowym*. Wyd. IUNG Puławy: 49-70.

WŁODEK S. 2007: *Możliwość wykorzystania ścieków i osadów ściekowych w uprawie roślin energetycznych.* Studia i Raporty IUNG – PIB, 8: 207-216.

[1]Szejniuk Bożena, [1]Budzińska Katarzyna, [1]Gałęzewska Beata, [1]Kubisz Łukasz
Department of Animal Hygiene and Microbiology of the Environment
University of Techonology and Life Sciences
ul. Mazowiecka 28, 85-084 Bydgoszcz, POLAND

[2]Wasilewski Piotr
Department of Plant Production and Experimenting
University of Techonology and Life Sciences
ul. Kordeckiego 20, 85-225 Bydgoszcz, POLAND