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RESPONSE OF MAIZE GROWN FOR SILAGE ON THE APPLICATION OF SEWAGE SLUDGE

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Abstract. Municipal sewage sludge has a lot of organic matter and is a rich source of nutrients, thus generating interest as a cheap fertilizer. The amount of the sewage sludge dose used in agriculture to fertilize crops is determined by law and its application should be in accordance with the rules of the EU. The problem is to determine the rate of release of nutrients from sewage sludge and intake speed of these components by the plants. The aim of this study was to evaluate the agricultural use of sewage sludge in the year of application and its residual effect in maize grown for silage. Maize variety 'PR39G12' was grown in the field after 5-year monoculture. Experiments were carried out according to the scheme: the control – without sewage sludge (mineral fertilizers); sewage sludge – the year of application, sewage sludge – the first year after application; sewage sludge – the second year after application. Sewage sludge was applied in the spring at a dose of 10 tonnes D.M.$\cdot$ha^{-1}, which was tested both in terms of microbial and heavy metal content. The amount of sewage sludge applied dose was in line with the regulations of Minister of Environment at that time [Directive... 2002] which allows the use of sludge in applied amount once every 5 years. Years in which the study was conducted were characterized by high volatility of weather conditions. There were significant differences in the amount and distribution of rainfall and the considerable volatility in the course of temperature in different periods of plant development. In the two years of the study (2006 and 2008) on the treatments where sewage sludge was applied in the first year, a trend of fewer plant losses was noted compared with plants with mineral fertilizer applied. Below-cob leaf greenness index showed no difference between the plants grown on mineral fertilizers and municipal sewage sludge, but the use of municipal sewage sludge contributed to cob set up. On the treatments fertilized with sewage sludge, plant productivity as fresh and dry matter yield of total maize plants was higher than on treatments with mineral fertilization.

Key words: fertilization, maize, sewage sludge, silage, yield

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INTRODUCTION

The development of civilization is associated with the development of ever larger amounts of waste, including municipal sewage. The main methods of municipal sewage sludge utilization in Poland, according to the Central Statistical Office [Statistical Yearbook... 2012], include agricultural use (25.3%), landfill (27.9%), land reclamation (26.5%), cultivation of plants intended for compost production (5.5%) and thermal transformation (14.8%). Municipal sewage sludge has a lot of organic matter and is a rich source of nutrients, thus generating interest as a cheap fertilizer. The value of municipal sewage sludge as a fertilizer was positively evaluated in a number of scientific studies [Nascimento *et al*. 2004, Jasiewicz *et al*. 2007, Sulewska and Koziara 2007, Krzywy *et al.* 2008a, Singh and Agrawal 2008, Niewiadomska *et al.* 2010, Vaca *et al*. 2011]. Agricultural use of municipal sewage sludge is legally regulated [Directive... 2012] and is mainly based on evaluation of the heavy metal content and its sanitary properties. Allowable amounts of sewage sludge that can be introduced into the soil according to the law do not constitute a direct threat to the environment. Note, however, that from the ecological point of view, components contained in the sewage sludge over many years can accumulate in the soil or be subject to loss by elution [Evanylo 1999].

Maize belongs to the group of plants with high nutritional requirements, and therefore to get the valuable forage, plants have to be supplied with enough nutrients for their development [Szulc *et al*. 2012]. These nutrients can be supplied either in the form of mineral or organic fertilizers. However, the excess of nutrients not used by the plants is dispersed in the soil, which may cause negative environmental effects. According to Sulewska *et al*. [2007], high nutritional requirements of maize are met mainly with nutrients derived from soil resources and supplied in the form of mineral fertilizers. Increasing crop yields, stimulated primarily by high fertilization, leads to a gradual depletion of certain soil nutrients, mainly micronutrients. These deficiencies can be enhanced when primarily nitrogen, phosphorus and potassium are delivered, as is commonly practiced in the intensive fertilization of soil. Metabolism of nutrients from mineral and organic fertilizers is well known, but the issue of the availability and utilization of nutrients from waste substances, such as municipal sewage sludge, remains still in the field of research. This issue is very important, because of the possibility of using a low-cost source of nutrients, that is municipal sewage sludge, which can significantly improve the biological value of biomass obtained [Gondek and Filipek-Mazur 2006]. Determination of the dose of sewage sludge used in agriculture to fertilize crops is not difficult, as it is regulated by the law [Directive... 2012]. According to Korboulewsky *et al*. [2002], the problem is to determine the rate of release of nutrients from sewage sludge and intake speed of these components by the plants. Such statements justify running research on cultivation of maize fertilized with municipal sewage sludge in different soil and climatic conditions.

The aim of this study was to evaluate the agricultural use of sewage sludge in the year of application and its residual effect in maize grown for silage.

MATERIAL AND METHODS

Experiments on the use of municipal sewage sludge were carried out in the fields of the Experimental Station in Swadzim, belonging to the Department of Agronomy at the

University of Life Sciences in Poznań. The study was conducted in 2006-2008. The single-factor experiment with the cultivation of maize for silage was established in a randomized block design with 4 replications. Maize variety 'PR39G12' was grown in the field after 5-year monoculture, with the single plots area of 22.4 m^2, two middle rows were harvested. Experiments were conducted as follows: control (mineral fertilizers); sewage sludge in the year of application; the first year after sewage sludge application; the second year after sewage sludge application. On the mineral-fertilized control treatment the following doses were applied: N – 130 $kg \cdot ha^{-1}$; P – 35 $kg \cdot ha^{-1}$; K – 116.2 $kg \cdot ha^{-1}$. The amount of organic matter in the tested sludge was increased by crop residue that was in the field after harvesting the raw material for silage. Sewage sludge was applied in the spring at a dose of 10 tonnes $DM \cdot ha^{-1}$, which was covered with a shallow plowing, and the basic components of NPK content were balanced in relation to the control. The amount of sewage sludge dose applied was in line with the regulation of the Minister of Environment at that time [Directive of the Minister of Environment 2002], which allows the use of sludge in the applied amount once every 5 years. Content of the basic components NPK brought to the soil with sewage sludge amounted to: N – 67.8 $kg \cdot ha^{-1}$, P – 13.3 $kg \cdot ha^{-1}$ and K – 49.2 $kg \cdot ha^{-1}$.

Soil analyzes from experimental field showed that the heavy metal content meets the limits of regulations of the Ministry of Environment established for the use of sewage sludge for agricultural purposes. Applied sewage sludge was tested in terms of its heavy metal content and microbiological composition at AQUANET Plant Research Laboratory in Koziegłowy. The chemical composition of the applied sewage sludge is given in Table 1. The chemical analyzes of sewage sludge showed that it is safe in terms of sanitary state and heavy metal content and does not exceed the limit values for sludge destined for agricultural use. The soil reaction at which the experiment was conducted, on average of three years of the study, amounted to 5.9.

Table 1. The chemical composition of sewage sludge applied

Specification	Sewage sludge
N total	6.78% D.M.
P	1.32% D.M.
K	4.92% D.M.
Ca	2.42% D.M.
Mg	0.48% D.M.
Cu	394 $mg \cdot kg^{-1}$ D.M.
Zn	925 $mg \cdot kg^{-1}$ D.M.
Cd	<2.5 $mg \cdot kg^{-1}$ D.M.
Pb	20.8 $mg \cdot kg^{-1}$ D.M.
Ni	14.4 $mg \cdot kg^{-1}$ D.M.
Cr	14.2 $mg \cdot kg^{-1}$ D.M.
Hg	0.77 $mg \cdot kg^{-1}$ D.M.
pH	7.1

Soil management was done in accordance with proper agricultural practice for silage maize. During the course of experiment during the growing season the quantitative status of plants was evaluated twice each year; in spring, i.e. after the full emergence (BBCH 12) and before harvest (BBCH 75). In addition, prior to harvest, productive cobs were counted and calculated per 1 m^2. During flowering (BBCH 67-70) plant height and the height of cob set up was measured for 25 consecutive plants in a row. On leaves below cobs at the flowering stage (BBCH 67), leaf greenness index was measured using the Hydro N-Tester in triplicate. This device works by measuring the absorption of light by the leaf at wavelengths – 650 and 940 nm. The quotient of these differences is an indication of the content of chlorophyll and is defined in SPAD units. The raw material for silage was harvested at milk-waxy maturity stage (BBCH 75) and determined yields of fresh and dry matter of whole plants, which are expressed in $Mg \cdot ha^{-1}$. In the yield of fresh and dry matter of raw material for silage, the percentage of cobs was also determined.

The effect of sewage sludge on the tested characteristics was analyzed based on standard analysis of variance (ANOVA) for orthogonal factorial experiments. The least significant difference (LSD) was verified by Student t test at $P \leq 0.05$ and $P \leq 0.01$.

RESULTS AND DISCUSSION

Years in which the study was conducted were characterized by a high volatility of weather conditions, as shown in Figure 1. There were significant differences in the amount and distribution of rainfall and the considerable volatility in the course of temperature in different periods of plant development. During 2006 there was the worst weather course among all the years of research, due to high temperatures during flowering in combination with extremely low rainfalls during that time. Drought, which appeared at the beginning of June and lasted until the first days of August (Fig. 1), caused low quantity and quality of the harvested crop as a result of reduction in cobs share. The years 2007-2008 were more favorable for maize growing, since during the peak of water demand for plants there was sufficient soil moisture, resulting in the proper growth and development of plants.

In all the years of the study, both the number of plants after emergence and the number of plants before harvest on the treatments where municipal sewage sludge was applied was not significantly different from the number of plants on the control treatment (Table 2). The analysis of variance also showed no significant differences in plant losses. It should be noted, however, that in two years of the study (2006 and 2008) on the treatments with the application of sewage sludge, there was a trend towards lower losses than in maize plants fertilized on the mineral treatment. As is clear from the data presented in Figure 1, those were growing seasons with extremely different weather conditions. An inverse relationship was found in 2007, which was characterized by a favorable course of weather conditions and the number of plant losses in the year of sewage sludge application was higher, compared with the control. It should also be noted that the residual effect of sludge in the second year after application resulted in a tendency to reduce the number of plant losses, as compared with the control. This relationship, however, failed to be confirmed statistically. So different maize plant response to fertilization with sewage sludge can be explained by diverse availability of individual nutrients from the sludge, suggesting the need to analyze each batch of sludge intended to fertilize plants [Krzywy *et al*. 2008b].

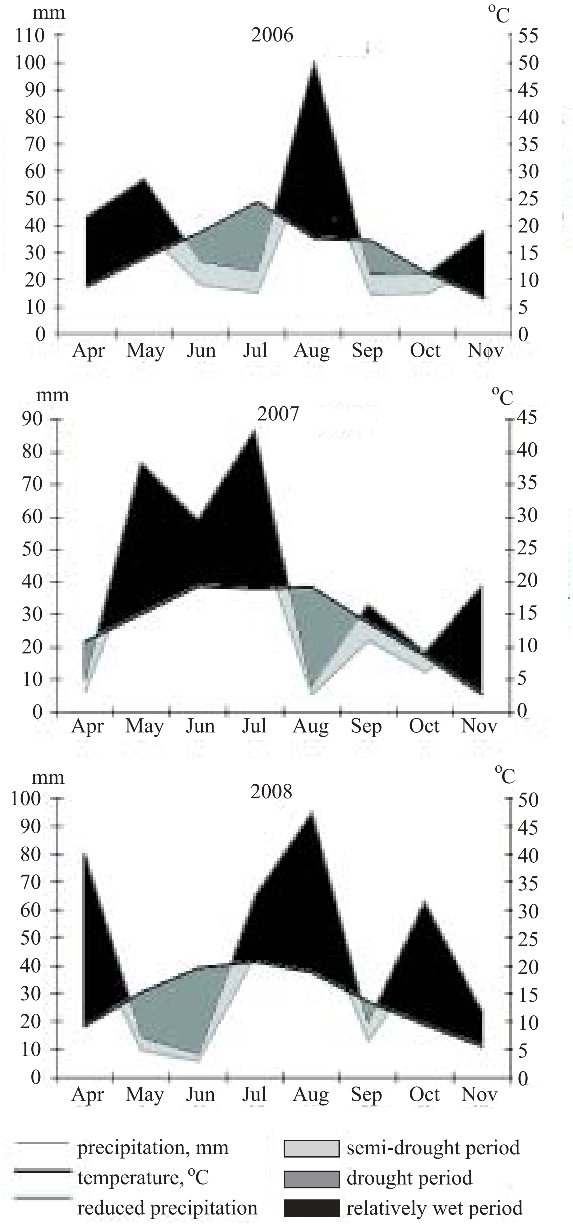

Fig. 1. Climatic graphs characterizing weather conditions in 2006-2008

Results of the evaluation of the below-cob leaf greenness index in Table 3 indicate that in the BBCH 65 stage there was no difference between the plants grown on mineral fertilizers and municipal sewage sludge. Application of sewage sludge did not improve the nutritional status of plants with nitrogen, and the value of SPAD units in 2008 was on the same level as that received by Sulewska and Koziara [2007] by fertilizing silage maize with full dose of manure. However, in 2006 and 2007, maize leaf greenness index in our study was much higher. The difference between the index of greenness of plants fertilized with manure and slurry in the study of Sulewska and Koziara [2007] and the value of SPAD units of plants fertilized with sewage sludge in the first two years of own research, ranged from 130 to 280. These authors also received lower values of maize leaf greenness index in the year of sewage sludge application than those shown in the first two years of our studies. Residual effect of sludge in our study did not diversify significantly maize leaf greenness index, but it was noted a trend for better nutrition of plants in the first year after treatment than in the year of application. This result does not support the arguments put forward by Reszel *et al*. [2004] that the effect of the use of sludge in the year of application is greater than the residual effect, which is related to the amount of available nutrients. Evanylo [1999] reported that from limed sludge in the first year on average 30% of N is available for plants, in the next year 15% of this component remains in the soil, and in the third year only 7%.

Table 2. The quantitative status of maize plants after the application of sewage sludge

Treatments	Plant number after emergence, pcs·m^2			Plant number before harvest, pcs·m^2			Plant losses %		
	2006	2007	2008	2006	2007	2008	2006	2007	2008
Control	8.2	8.3	9.0	7.7	8.2	8.8	6.2	1.6	3.0
Sewage sludge in year of application	8.9	8.9	9.4	8.6	8.6	9.4	3.2	3.5	0.2
Residual effect in the first year		8.7	8.7		8.4	8.4		2.8	3.0
Residual effect in the second year			9.2			9.0			2.1
LSD	ns	ns	ns	ns	ns	ns	ns	ns	ns

ns – non-significant differences

Table 3. Below-cob leaf greenness index in [SPAD] units after the application of sewage sludge

Treatments	Below-cob leaf greenness index in SPAD units			Mean/ ±SD
	2006	2007	2008	
Control	522.0	729.9	405.7	552.5
Sewage sludge in year of application	529.7	670.2	361.2	520.4
Residual effect in the first year		696.5	390.0	543.2
Residual effect in the second year			351.0	± 77.7
LSD	ns	ns	ns	

ns – non-significant differences

Plant height in the first two years of the study did not change significantly under the influence of municipal sewage sludge (Table 4). During favorable conditions for growth and development of maize in 2008, on the treatments after first year of sludge application, a tendency to increase the plant height was observed, as compared with the control. These results were not confirmed in a study conducted by Jarausch-Wehrheim *et al*. [1996], in which corn was fertilized with two doses of sludge and no differences in height and the total leaf area were found compared with treatments fertilized with manure. Residual effect of sewage sludge resulted in a decrease of plant height. Significantly the lowest plant height was found on the treatments in the second year after the application of municipal sewage sludge. The difference in height between these treatments and plants with mineral fertilization (control) was approximately 11 cm.

Decrease in the height of plants over the years after the application of sewage sludge may be related to the amount of available nutrients in soil. This thesis is consistent with the results of the observation of the effects of sludge already cited by Reszel *et al.* [2004] and Evanylo [1999].

Table 4. The morphological characteristics of mature maize plants after the application of sewage sludge

Treatment	Plant height, cm			Height of cob establishing, cm		
	2006	2007	2008	2006	2007	2008
Control	243.7	286.2	175.1^b	110.9	125.5	55.5
Sewage sludge in year of application	241.7	284.5	180.1^b	108.2	124.4	55.9
Residual effect in the first year		281.5	174.2^b		118.7	56.2
Residual effect in the second year			164.1^a			51.5
LSD	ns	ns	6.36**	ns	ns	ns

*, ** indicate statistical significance at the 5% and 1% levels of probability
ns – non-significant differences
a, b, c, ….. – values followed by the same letter are not significantly different at the 0.05 or 0.01 level according to the t-Student test

The height of maize cob set up did not change significantly after the influence of municipal sewage sludge (Table 4). Sludge used in the experiment also showed no positive residual effect, because a tendency to reduce the height of cob set up was noticed along the years after its application.

The use of municipal sewage sludge favored establishing cobs of maize plants (Table 5).

Table 5. Cob number after the application of sewage sludge, pcs.·m^2

Treatment	Number of cobs, pcs.·m^2			Mean/ ±SD
	2006	2007	2008	
Control	6.6^a	7.7	9.1	7.8
Sewage sludge in year of application	7.8^b	8.7	9.3	8.6
Residual effect in first year		8.2	9.5	8.8
Residual effect in second year			9.2	± 1.14
LSD	1.07*	ns	ns	

for explanations, see Table 4

This was particularly evident in the first year of the study in extremely dry conditions, when the plants fertilized with sewage sludge formed a significantly higher amount of cobs (18.2%) than those fertilized with mineral fertilizers (control). Good effect of sewage sludge in not so favorable moisture conditions for the growth and development of maize plants can be found in the fact that the sludge is characterized by high hygroscopicity [Żurawski *et al.* 1997], allowing to capture and collect the water, improving its retention in the soil. This is confirmed by the results of our own research. These results are confirmed by Reszel *et al.* [2004] stating that the effect of sewage sludge application on setting up the cobs is stronger than mineral fertilization. In the second year of the study, characterized by more favorable weather conditions this trend was also noticed, and after fertilization with sewage sludge approximately 13.0% more cobs were established than in the control, which, however, failed to be proved statistically. It was a different result than that obtained by Vaca *et al*. [2011]. In the next two years after sludge application there was no significant increase in the number of established cobs, but a positive trend occurred in 2008.

On the treatments fertilized with sewage sludge crop productivity expressed in fresh and dry matter yields of whole maize plants was higher than on treatments where mineral fertilizers were used (Tables 6, 7). Three-year study results indicate a statistically significant increase in both the yield of fresh and dry matter of whole plants in the year of application of municipal sewage sludge, as compared with the control. The largest increase in the yield of fresh and dry matter was recorded in the extremely dry 2006, and the increase amounted to 7.9 $Mg \cdot ha^{-1}$ and 4.2 $Mg \cdot ha^{-1}$. Obtaining such a good effect of sewage sludge application under drought conditions can be related with the already mentioned high hygroscopicity of sewage sludge, which captures and collects water [Żurawski *et al*. 1997] and then makes it available to the plants, which could cause yield increase. The increase in sorption capacity of soil fertilized with sewage sludge is also indicated in the study of Jasiewicz *et al*. [2007]. Our findings were also confirmed in a study conducted by Reszel *et al*. [2004] which states that the most active effect of sewage sludge on maize is observed in the first year after application. However, according to Nogueira *et al*. [2009], even nine-year maize fertilization with sewage sludge at different doses does not cause a significant increase in dry matter yield of maize, as compared with mineral fertilization. Similar results were achieved by Mantovi *et al*. [2005]. Also Gondek and Filipek-Mazur [2003], who studied the response of maize fertilized with sewage sludge compost in the pot experiment, obtained the highest dry matter yield of cobs at the treatments with mineral fertilizers. Similar results were also obtained by these authors in a later study of spring wheat [Gondek *et al*. 2012]. In the literature, however, many reports indicate that the use of natural fertilizers, sewage sludge or mixtures of peat in maize growing, allows to achieve significantly higher yields and is more efficient than mineral fertilization [Jarausch-Wehrheim et al. 1996, Cuevas *et al*. 2003, Sulewska and Koziara 2007, Gondek and Filipek-Mazur 2008, Niewiadomska *et al*. 2010, Vaca *et al*. 2011]. A similar result was obtained in our study, because the yield of fresh and dry matter on the treatments in both the first and the second year after application of the sludge were higher than in the treatments with mineral fertilization. A different opinion on this subject is presented by Bazzoffi *et al*. [1998], who did not obtain a higher grain yield of maize fertilized with compost from municipal sewage sludge than on the treatments with mineral fertilization. The authors believe that the lack of increase in maize grain yield may be due to the inhibitory effect of heavy metals contained in sludge. However, Melo *et al*. [2007] and Vaca *et al*. [2011], who studied maize fertilized with municipal sewage sludge, showed that the occurrence of heavy metals in sediments do not have any toxic effects on the growth and development of this crop.

Our study also showed that the positive residue effect of sludge on fresh and dry matter yields of the whole plant in the first year after application remained only in the last year of the study. Yields of the whole plant fresh matter, as compared with the yield of the treatments harvested in the year of sludge application, were higher by 2.1 $Mg \cdot ha^{-1}$, while the dry matter yields were higher by 0.5 $Mg \cdot ha^{-1}$. Such an increase in yield, although not statistically proven, could be a reaction to the easier access to plant nutrients, mainly nitrogen, whose availability from sewage sludge, however, depends on the weather conditions during the growing season, the dose of sludge and C: N ratio [Barbartik *et al*. 1985]. Gondek *et al*. [2012] also showed a yield increase of spring wheat grain in the third year after the application of sludge, which according to the authors was the result of increased availability of nutrients from the sludge. However, in our study, the residual effect of municipal sewage sludge is not maintained in the second year after application. Melo *et al*. [2007] and Vaca *et al*. [2011] argue that the increase in yield of maize fertilized with sewage sludge can be explained by the fact that a very large amount of organic matter rich in nitrogen is introduced into the soil along with sludge, which improves the soil properties and increases the nutrients available for plants. However, according to Gondek *et al*. [2012], limited access to plant nitrogen compounds contained in sewage sludge, especially in the year of sludge application, may decide on the amount and quality of the harvested crop. According to the authors, better effect of sewage sludge can be obtained using them together with minerals. The authors also believe that the effectiveness of sewage sludge fertilizer applied in the spring time is less than when it is introduced in the autumn fertilization. On the one hand, the spring application of sewage sludge limits the availability of nutrients for plants, but on the other hand it reduces the losses caused by leaching into the soil profile during autumn and winter.

Table 6. Fresh matter yield of maize plant after the application of sewage sludge, $Mg \cdot ha^{-1}$

Treatment	Year			Mean/ ±SD
	2006	2007	2008	
Control	35.8[a]	44.6[a]	29.4[a]	36.6
Sewage sludge in year of application	43.7[b]	47.8[b]	33.0[bc]	41.5
Residual effect in first year		43.6[a]	35.1[c]	39.3
Residual effect in second year			30.8[ab]	± 2.21
LSD	2.22**	1.63**	2.44**	

for explanations, see Table 4

Table 7. Dry matter yield of maize plant after the application of sewage sludge, $Mg \cdot ha^{-1}$

Treatment	Year			Mean/ ±SD
	2006	2007	2008	
Control	17.9[a]	23.0[a]	13.1[a]	18.0
Sewage sludge in year of application	22.1[b]	26.8[c]	15.1[b]	21.3
Residual effect in first year		24.4[b]	15.6[b]	20.0
Residual effect in second year			13.6[a]	± 1.45
LSD	1.21**	1.07**	1.28**	

for explanations, see Table 4

Three-year study results indicate that share of cobs without leaves in the raw material for silage did not change significantly under the influence of municipal sewage sludge (Tables 8, 9). Both in the first and in the third year of the study, the best composition of silage was obtained on treatments fertilized with mineral. However, in 2007, the use of sewage sludge contributed to a slightly larger share of cobs without leaves in plant material for ensiling.

The use of sewage sludge in maize grown for silage was reflected in the level of yield and its structure components (Table 10). The calculated coefficients of variation indicate that sewage sludge fertilization of maize grown for silage stabilized the yields and the share of cobs without leaves in the yield of fresh and dry matter of raw material for silage compared to that fertilized with minerals. The exception was the dry matter yield of whole plants, which under the influence of sewage sludge was characterized by greater volatility (26.6%) than in controls. Fertilization with sewage sludge also caused increase in calculated medium and maximum values for share of cobs without leaves, but not the number of cobs.

Table 8. Share of cobs without leaves in fresh matter yield of maize plant after the application of sewage sludge, %

Treatment	Year			Mean/ ±SD
	2006	2007	2008	
Control	37.4	43.6	55.4	45.5
Sewage sludge in year of application	35.0	44.9	54.2	44.7
Residual effect in the first year		43.4	49.8	46.6
Residual effect in the second year			52.0	± 8.2
LSD	ns	ns	ns	

ns – non-significant differences

Table 9. Share of cobs without leaves in dry matter yield of maize plant after the application of sewage sludge, %

Treatment	Year			Mean/ ±SD
	2006	2007	2008	
Control	41.5	42.3	58.2	47.3
Sewage sludge in year of application	39.5	44.4	56.8	46.9
Residual effect in the first year		42.1	51.3	46.7
Residual effect in the second year			53.5	± 8.8
LSD	ns	ns	ns	

ns – non-significant differences

Table 10. Statistical characteristics of some features of maize silage on treatments without and after the application of sewage sludge

Trait	Treatment	Mean	Minimum	Maximum	SD	CV%
Cob number, pcs.$\cdot$m^2	control	7.8	5.5	10.0	1.3	16.8
	sewage sludge	8.8	6.8	10.0	0.9	9.9
Share of cobs without leaves in fresh matter yield of plants, %	control	45.5	36.7	63.4	8.9	19.6
	sewage sludge	46.5	31.9	64.1	8.1	17.3
Share of cobs without leaves in dry matter yield of plants, %	control	47.3	38.6	66.2	9.1	19.2
	sewage sludge	47.9	36.8	66.7	7.8	16.3
Fresh matter yield of plants, Mg$\cdot$ha^{-1}	control	36.6	28.3	45.9	6.4	17.5
	sewage sludge	39.0	28.6	49.2	6.6	17.0
Dry matter yield of plants, Mg$\cdot$ha^{-1}	control	18.0	12.3	24.2	4.2	23.2
	sewage sludge	19.6	12.0	27.4	5.2	26.6

CONCLUSIONS

1. The results indicate that the growth and development of maize fertilized with municipal sewage sludge was normal and did not differ from mineral-fertilized plants. The use of municipal sewage sludge did not diversify the quantitative status of plants and maize leaf greenness index.

2. Sludge fertilized maize yielded higher than the control treatments, especially under extreme conditions of drought. Positive effects of sewage sludge were manifested in stable yield cobs share without leaves compared with mineral fertilization.

3. The study confirmed the legitimacy of the application of municipal sewage sludge in maize grown for silage.

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REAKCJA KUKURYDZY UPRAWIANEJ NA KISZONKĘ NA STOSOWANIE OSADÓW ŚCIEKOWYCH

Streszczenie. Komunalne osady ściekowe zawierają dużo substancji organicznej i są bogatym źródłem składników pokarmowych, dlatego też budzą zainteresowanie jako tani nawóz. Wysokość dawki osadu ściekowego stosowanego w rolnictwie do nawożenia roślin uprawnych jest prawnie uwarunkowana, a jego stosowanie powinno odbywać się zgodnie z przepisami obowiązującymi w UE. Problem stanowi określenie tempa uwalniania składników pokarmowych z osadów ściekowych oraz szybkości pobierania tych składników przez rośliny. Celem badań była ocena rolniczego wykorzystania komunalnych osadów ściekowych w roku stosowania oraz ich następczego działania w uprawie kukurydzy na kiszonkę. Kukurydzę odmiany PR39G12 uprawiano na polu po 5-letniej monokulturze. Doświadczenia przeprowadzono według schematu: kontrola – bez osadu (nawożenie mineralne); osad ściekowy w roku zastosowania; osad ściekowy I rok po zastosowaniu; osad ściekowy II rok po zastosowaniu. Osad ściekowy, który sprawdzono zarówno pod względem zawartości metali ciężkich, jak i mikrobiologicznym, aplikowano wiosną w dawce 10 ton s.m.$\cdot$ha^{-1}. Wysokość zastosowanej dawki osadu ściekowego była zgodna z ówczesnym rozporządzeniem Ministra Środowiska [Rozporządzenie... 2002] dopuszczającym stosowanie osadu w tej ilości raz na 5 lat. Lata, w których prowadzono badania, odznaczały się dużą zmiennością przebiegu warunków pogodowych. Stwierdzono znaczne różnice w ilości i w rozkładzie opadów oraz znaczną zmienność przebiegu temperatur w poszczególnych okresach rozwoju roślin. W dwóch latach badań (2006 i 2008) w roku zastosowania osadu ściekowego zauważono tendencję do mniejszej liczby zaników roślin kukurydzy w porównaniu z roślinami nawożonymi mineralnie. Ocena wskaźnika zieloności liścia przykolbowego kukurydzy nie wykazała różnic pomiędzy roślinami uprawianymi na nawozach mineralnych, jak i komunalnych osadach ściekowych, natomiast zastosowanie komunalnych osadów ściekowych sprzyjało zawiązywaniu kolb. Po nawożeniu osadami ściekowymi produktywność wyrażona plonami świeżej i suchej masy całych roślin kukurydzy była wyższa niż wtedy, gdy zastosowano nawożenie mineralnie.

Słowa kluczowe: kiszonka, kukurydza, nawożenie, osady ściekowe, plon

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