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THE EFFECT OF INCREASING DOSES OF MEAT-AND-BONE MEAL ON THE YIELD AND MACRONUTRIENT CONTENT OF PERENNIAL RYEGRASS (*LOLIUM PERENNE* L.)

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Key words: perennial ryegrass, yield, macronutrients, meat-and-bone meal.

Abstract

The effect of three increasing doses of meat-and-bone meal on the yield and macronutrient content of perennial ryegrass (*Lolium perenne* L.) was studied during a two-year pot experiment (2005–2006). Meat-and-bone meal was applied in a single dose in 2005, before sowing. The meal was mixed with soil in the following dosage: 0.25, 0.5 and 1.0% per 10 kg soil per pot. The effect of meat-and-bone meal was compared with that of NPK fertilizers (control treatment) applied at the following rates: 1 g N, 0.5 g P and 1 g K per pot. Pots filled with soil mixed with meat-and-bone meal were also fertilized with 1 g potassium. The results were verified statistically by one-way analysis of variance in a completely randomized design.

The increasing doses of meat-and-bone meal had a significant effect on the yield and macronutrient content of perennial ryegrass. Meat-and-bone meal applied in a dose of 0.5% and 1% caused an 11% increase in the dry matter yield of perennial ryegrass over two years, compared with the control treatment (NPK). A beneficial residual effect of meat-and-bone meal was noted only for the highest dose, while the lowest dose (0.25%) caused a 3.5-fold yield decrease, which led to a 30% drop in the total yield of perennial ryegrass over two years. The above suggests that the dose of 0.25% was insufficient to meet the nutrient requirements of perennial ryegrass during two consecutive years. Meat-and-bone meal applied in a dose of 0.5% contributed to the most desirable mineral composition of perennial ryegrass, whereas the highest dose of meat-and-bone-meal resulted in excess accumulation of nitrogen and potassium in plants, thus inhibiting magnesium uptake.

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WPŁYW WZRASTAJĄCYCH DAWEK MĄCZKI MIĘSNO-KOSTNEJ NA PLON I ZAWARTOŚĆ MAKROSKŁADNIKÓW W ŻYCICY TRWAŁEJ (*LOLIUM PERENNE* L.)

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Słowa kluczowe: życica trwała, plon, makroskładniki, mączka mięsno-kostna.

Abstrakt

W dwuletnim doświadczeniu wazonowym (2005–2006) badano wpływ trzech wzrastających dawek mączki mięsno-kostnej na plon i zawartość makroskładników w życicy trwałej (*Lolium perenne* L.). Mączkę mięsno-kostną zastosowano jednorazowo, przedsiewnie w 2005 r., mieszając z glebą w dawkach: 0,25, 0,5 i 1,0% mączki w stosunku do masy (10 kg) gleby w wazonie. Działanie mączki porównywano z nawożeniem NPK (obiekt kontrolny) w ilości: 1 g N, 0,5 g P i 1 g K na wazon. Potas w ilości 1 g zastosowano również do wazonów z mączkami. Wyniki opracowano statystycznie metodą analizy wariancji dla doświadczeń jednoczynnikowych w układzie całkowicie losowym.

Z badań wynika, że zastosowanie wzrastających dawek mączki mięsno-kostnej istotnie różnicowało plon i zawartość badanych makroskładników w życicy trwałej. Pod wpływem średniej (0,5%) i najwyższej (1%) dawki mączki stwierdzono 11-procentowy wzrost plonu suchej masy życicy trwałej za dwa lata, w porównaniu z plonem obiektu kontrolnego (NPK), przy czym korzystne działanie następcze mączki uwidoczniło się tylko w przypadku najwyższej dawki. Najmniejsza (0,25%) dawka mączki spowodowała natomiast w działaniu następczym średnio ponad 3,5-krotny spadek plonu, co skutkowało 30-procentowym spadkiem sumy plonu z dwóch lat. Można więc wnioskować, że jest to zbyt mała dawka dla badanej trawy na dwa lata wegetacji. Życica trwała uprawiana na średniej dawce mączki miała najkorzystniejszy skład mineralny, natomiast najwyższa dawka mączki powodowała nadmierną kumulację azotu i potasu w roślinie, co blokowało pobieranie magnezu.

Introduction

Meat-and-bone meal produced from the lowest-risk leftovers of the slaughtering process can be used as an organic fertilizer and a soil amendment (MAĆKOWIAK 2005). Animal meals have been increasingly applied to improve soil fertility in recent years, due to a considerable decrease in livestock population and the production of organic fertilizers accompanied by an increase in the prices of mineral fertilizers (SPYCHAJ-FABISIAK et al. 2007, KRZYWY et al. 2004). Meat-and-bone meals are a rich source of nutrients for plants, in particular nitrogen and phosphorus as well as magnesium, calcium and microelements. According to JENG et al. (2004), nitrogen supplied by meat-and-bone meal meets 80% of the nitrogen demand of grain crops. In comparison with manure, the dry matter of meat-and-bone meal contains approximately 4-fold more nitrogen, 10-fold more phosphorus and 8-fold more calcium, as well as over 4-fold less potassium and nearly 2-fold less magnesium.

Both fertilizers have a similar organic matter content. Owing to their beneficial influence on soil fertility and plant production, animal meals could be used on a larger scale in farms where no organic fertilizers are produced.

The aim of this study was to determine the direct and residual effect of increasing meat-and-bone meal doses on the yield and macronutrient content of perennial ryegrass.

Materials and Methods

A two-year (2005–2006) pot experiment involving perennial ryegrass (*Lolium perenne* L.) cv. Naki was conducted in the greenhouse of the University of Warmia and Mazury in Olsztyn. Modified Kick-Brauckmann pots were filled with slightly acidic (pH in 1 mol KCl $dm^{-3} = 5.0$) proper brown soil developed from loamy sand, with a high content of available phosphorus (85.0 mg P kg^{-1}) and potassium (116.2 mg K kg^{-1}) and an average content of available magnesium (28.0 mg Mg kg^{-1}). Meat-and-bone meal containing blood and feather hydrolyzate powder was applied in a single dose, in the first year of the study, before sowing. It was mixed with soil in the following dosage: 0.25, 0.5 and 1.0% per 10 kg soil per pot. The meal contained 96.05% dry matter, 71.42% organic matter, 27.64% crude ash, 13.69% crude fat, 7.88% total nitrogen, 4.67% phosphorus, 0.34% potassium, 10.03% calcium, 0.68% sodium and 0.20% magnesium. According to the classification of animal by-products, the meal used in the study was category 3 material which comprises animal by-products derived from the production of products intended for human consumption. Pots filled with soil mixed with meat-and-bone meal were also fertilized with 1.0 g K pot^{-1} in the first and second year of the experiment, before sowing. The effect of meat-and-bone meal was compared with that of NPK fertilizers (control treatment): 1 g N (two doses of 0.5 g, before sowing and after the first harvest, in the form of $CO(NH_2)_2$), 0.5 g P (KH_2PO_4) and 1 g K (KH_2PO_4 and KCl) per pot applied pre-sowing in the first and second year of the study. Soil moisture in pots was maintained at a level of 60% maximum capillary water capacity.

Samples of three perennial ryegrass regrowths harvested in the first and second growing season were subjected to chemical analyses. The collected samples were mineralized in concentrated sulfuric acid with hydrogen peroxide as the oxidizing agent. Wet mineralized samples were assayed for the content of: total nitrogen – by the hypochlorite method, phosphorus – by the vanadium-molybdenum method, calcium, potassium and sodium – by atomic emission spectrometry (AES), and magnesium – by atomic absorption spectrometry (AAS). The results (the dry matter yield and the macronutrient

content of perennial ryegrass) were verified statistically by one-way analysis of variance in a completely randomized design, in four replications, at a significance level of $p = 0.01$.

Results and Discussion

The increasing doses of meat-and-bone meal containing blood and feather hydrolyzate powder, applied once during a two-year period, had a significant effect on perennial ryegrass yield (Table 1). In the first year of the study, meat-and-bone meal applied in the highest dose of 1% caused a significant, 3.5-fold decrease in the dry matter yield of the first perennial ryegrass regrowth compared with the control treatment, and an over 4-fold decrease relative to treatments fertilized with lower meal doses. Lower doses of meat-and-bone meal (0.25 and 0.5%) increased perennial ryegrass yield by around 30% (compared with the control treatment), but the noted differences were statistically non-significant. In the treatment fertilized with 0.5% meal, the yield of the second perennial ryegrass regrowth was significantly higher relative to the remaining treatments, and over 2-fold higher in comparison with the control treatment. The application of 0.5% meal contributed to the highest yield of three regrowths (74.8 g d.m.), which enabled to obtain a nearly

Table 1

The effect of meat and bone meal applied at different doses on the dry matter yield of perennial ryegrass [g pot^{-1}]

Year	Treatment [%]	Regrowth			Total yield of three regrowths
		I	II	III	
2005	NPK	17.6	17.0	5.8	40.4
	0.25	22.4	18.2	6.5	47.1
	0,5	23.1	39.6	12.1	74.8
	1	5.1	14.9	17.9	37.9
Mean		17.0	22.4	10.6	50.0
$NIR_{0.01}$		9.5	20.0	r.n.	
2006	NPK [%]	18.2	18.7	7.5	44.4
	0.25	3.7	4.2	4.3	12.2
	0.5	5.6	6.1	5.6	17.3
	1	13.2	17.8	25.4	56.4
Mean		10.2	11.7	10.7	32.6
$NIR_{0.01}$		4.8	12.7	r.n.	
Total yield for two years	NPK [%]	35.8	35.7	13.3	84.8
	0.25	26.1	22.4	10.8	59.3
	0.5	28.7	45.7	17.7	92.1
	1	18.3	32.7	43.3	94.3
Mean		27.2	34.1	21.3	82.6

two-fold yield increment, compared with the control treatment. JENG et al. (2006) also applied increasing meat-and-bone meal doses and reported a significant increase in the dry matter yield of perennial ryegrass in both pot and field experiments.

In the second year of the experiment, the yield of the first perennial ryegrass regrowth was significantly lower than in the control treatment, regardless of the meal dose. The highest, approximately 5-fold, yield decrease was observed in treatments fertilized with the lowest dose (0.25%) of meat-and-bone meal. The yield of the second regrowth was approximately 4.5-fold lower in this treatment, relative to the control (significant difference). The highest annual and two-year yield (56.4 and 94.3 g d.m. per pot respectively) was obtained following the application of the highest (1%) meal dose, in both years of the study.

The results of the two-year experiment show that meat-and-bone meal applied pre-sowing in a single dose of 0.5% and 1% per pot caused an 11% increase in the dry matter yield of perennial ryegrass, compared with the control treatment. Similar data were reported for meadow fescue fertilized with animal meal (NOGALSKA, CZAPLA 2009). In experiments performed by STĘPIEŃ and MERCIK (2002), and GÓRECKA et al. (2009), the yields of triticale, serradella and rapeseed fertilized with animal meals were similar to or higher than in the control treatment. In the present study, the lowest dose (0.25%) of meat-and-bone meal caused a 3.5-fold yield decrease, which led to a 30% drop in the total yield of perennial ryegrass over two years, relative to the control treatment. The above suggests that the dose of 0.25% was insufficient to meet the nutrient requirements of perennial ryegrass during two consecutive years.

The macronutrient content of perennial ryegrass dry matter changed substantially but irregularly under the influence of increasing animal meal doses. In the first year of the experiment, the nitrogen content of the studied grass increased significantly as a result of the application of the highest meal dose (1%) in three regrowths, the medium dose (0.5%) in the first and third regrowth and the lowest dose (0.25%) in the first regrowth (Table 2). Depending on fertilization levels, the average nitrogen content of perennial ryegrass ranged from 9.86 to 30.66 g N kg^{-1} d.m., which corresponded to 6.16–19.16% protein. Protein content close to the optimum value of 16.46% determined for *Lolium perenne* (FALKOWSKI et al. 2000) was noted in all regrowths of plants fertilized with the highest meal dose and in the first regrowth of plants fertilized with 0.5% meat-and-bone meal. Relative to the control, the nitrogen content of perennial ryegrass increased almost 3-fold and 1.5-fold in the treatment fertilized with 1% and 0.5% meal, respectively.

Table 2

The effect of meat-and-bone meal dosage on the concentrations of N, P and K in perennial ryegrass biomass [g kg^{-1} d.m.]

Year	Treatment	N				P				K			
		regrowth											
		I	II	III	weighted mean	I	II	III	weighted mean	I	II	III	weighted mean
2005	NPK [%]	11.25	11.71	5.95	10.68	5.64	5.80	8.19	6.07	47.13	26.50	27.88	35.68
	0.25	22.86	4.18	5.74	13.28	5.46	3.63	4.98	4.14	53.00	31.63	24.75	40.84
	0.5	29.68	11.20	9.15	16.57	5.89	4.44	4.51	4.90	57.25	31.25	23.75	38.07
	1	45.25	30.51	26.63	30.66	6.95	5.86	5.11	5.65	37.25	50.00	39.50	43.32
Mean		27.26	14.40	11.87	17.83	5.98	4.93	5.70	5.53	48.66	34.84	28.97	37.49
Weighted mean		–	–	–	17.80	–	–	–	5.19	–	–	–	39.48
$NIR_{0.01}$		10.01	6.69	3.86	–	0.88	1.48	1.41	–	5.28	11.50	r.n.	–
2006	NPK [%]	14.40	12.70	4.60	12.03	5.20	3.98	5.35	4.71	26.75	21.45	23.05	23.89
	0.25	12.48	13.05	4.48	9.86	7.70	7.72	5.85	7.05	23.25	23.00	36.25	27.75
	0.5	11.70	17.03	7.50	12.22	6.43	7.90	5.65	6.70	19.70	20.85	31.88	24.02
	1	40.73	31.75	6.65	22.55	6.38	4.53	4.28	4.85	31.82	25.53	34.13	30.87
Mean		19.83	18.63	5.81	14.76	6.43	6.03	5.28	5.91	25.38	22.67	31.33	26.47
Weighted mean		–	–	–	14.16	–	–	–	5.83	–	–	–	26.63
$NIR^{0.01}$		6.05	15.52	r.n.	–	r.n.	2.34	r.n.	–	8.61	r.n.	10.06	–

In the second year of the experiment, a significant residual effect of the highest meat-and-bone meal dose was noted in the first and second perennial ryegrass regrowth which contained 40.73 and 31.75 g N kg^{-1} d.m. on average, respectively, resulting in an over 2.5-fold increase in nitrogen content, compared with control plants. The average nitrogen content of perennial ryegrass increased along with an increase in meal dose in both years of the study. Similar changes in nitrogen concentrations were observed in meadow fescue fertilized with increasing doses of meat-and-bone meal (NOGALSKA, CZAPLA 2009).

In the first and second year of the study, the average phosphorus content of perennial ryegrass ranged from 4.14 to 7.05 g P kg^{-1} d.m. According to FALKOWSKI et al. (2000), grassland vegetation should contain 2.8 to 3.6 g P kg^{-1} d.m. The phosphorus content of the studied grass was over 1.5-fold higher than the above optimum values. NOWAK and DRASZAWKA-BOŁZAN (2001) also reported high phosphorus concentrations in perennial ryegrass, at 4.6–5.4 g P kg^{-1}. STĘPIEŃ and MERCIK (2002) demonstrated that among various animal by-products, meat-and-bone meal supported the highest increase in the phosphorus content of test plants. In the current experiment, a significant increase in phosphorus concentrations was noted in the first regrowth (2005) of perennial ryegrass fertilized with the highest meat-and-bone meal dose and

in the second regrowth (2006) of plants fertilized with lower meal doses. Relative to the control, the second perennial ryegrass regrowth fertilized with the lowest meal dose and the third regrowth of plants in all treatments contained significantly less phosphorus in the first year of the study.

The optimum potassium content of animal feed is 17.0 g K kg^{-1} d.m. Potassium deficiency is seldom observed in grasslands (FALKOWSKI et al. 2000). The average potassium content of perennial ryegrass was high, at 23.89 to 43.32 g K kg^{-1} d.m. Equally high potassium concentrations in perennial ryegrass were reported by WOŁOSZYK and KRZYWY (1999), and NOWAK and DRASZAWKA-BOŁZAN (2001). In the first year of the current study, meat-and-bone meal applied in a dose of 0.25 and 0.5% caused a significant increase, and the highest meal dose contributed to a significant decrease in the potassium content of the first perennial ryegrass regrowth, compared with the control treatment. The highest meal dose significantly increased potassium concentrations in the second regrowth. In the second year, perennial ryegrass contained over 30% less potassium than in the first year. Grass fertilized with the highest and lowest dose of animal meal was most abundant in potassium.

The present results and the findings of other authors (WOŁOSZYK, KRZYWY 1999, FALKOWSKI et al. 2000, NOWAK, DRASZAWKA-BOŁZAN 2001, NOGALSKA, CZAPLA 2009) indicate that potassium has an antagonistic effect on magnesium uptake by grasses (Table 3). Excess potassium accumulation in perennial ryegrass decreased the magnesium content of plants. Perennial ryegrass fertilized with the highest meat-and-bone meal dose contained large amounts of nitrogen, which could inhibit magnesium uptake (KOCHANOWSKA, NOWAK 1992). The magnesium content of perennial ryegrass varied subject to fertilization and regrowth, ranging from 1.69 to 4.11 g Mg kg^{-1} d.m. In both years of the experiment, perennial ryegrass had the highest magnesium content in treatments fertilized with 0.5% meal (18% increase relative to the control). In the second year, perennial ryegrass was less abundant in magnesium, by 30% on average, although all meal doses contributed to an increase in magnesium content, compared with the control treatment. Hay produced in Poland often contains insufficient quantities of magnesium. In animal nutrition, the threshold value is 2.0 g Mg kg^{-1} d.m. plants (FALKOWSKI et al. 2000).

The average calcium content of perennial ryegrass was in the range of 4.55 to 12.92 g Ca kg^{-1} d.m. The optimum value of 7.0 g Ca kg^{-1} d.m. (FALKOWSKI et al. 2000) was achieved in all treatments in the first year of the experiment, and in the treatment fertilized with the highest meat-and-bone meal dose in the second year. In the first year of the study, lower meal doses caused a significant (1.5-fold) increase in the calcium content of the first ryegrass regrowth. All meal doses exerted a similar effect on calcium concentrations in the third regrowth. In the second year of the experiment, perennial ryegrass contained

Table 3

The effect of meat-and-bone meal dosage on the concentrations of Mg, Ca and Na in perennial ryegrass biomass [g kg^{-1} d.m.]

Year	Treatment	Mg				Ca				Na			
		regrowth											
		I	II	III	weighted mean	I	II	III	weighted mean	I	II	III	weighted mean
2005	NPK [%]	1.95	3.84	4.00	3.04	7.65	9.00	8.10	8.29	0.68	0.72	0.83	0.71
	0.25	2.73	2.92	3.68	2.93	11.35	10.75	10.70	11.03	0.93	1.26	1.24	1.10
	0.5	2.66	3.64	5.25	3.60	11.15	12.18	12.80	11.96	1.82	3.33	2.32	2.70
	1	1.41	2.79	3.51	2.94	7.4	12.30	15.00	12.92	1.17	2.67	3.88	3.04
Mean		2.19	3.30	4.11	3.20	9.40	11.06	11.65	10.70	1.30	2.00	2.07	1.78
Weighted mean		–	–	–	3.13	–	–	–	11.05	–	–	–	1.89
$NIR_{0.01}$		0.23	0.65	0.92	–	1.48	r.n.	1.69	–	0.49	1.08	0.98	–
2006	NPK [%]	1.60	2.15	2.45	1.97	4.15	4.55	5.53	4.55	1.33	1.53	2.30	1.58
	0.25	1.65	2.75	1.93	2.13	5.13	3.85	5.47	5.02	1.38	1.08	1.28	1.24
	0.5	1.65	2.98	2.23	2.31	4.63	4.15	6.08	4.93	1.08	0.8	1.30	1.05
	1	1.85	2.58	2.05	2.17	7.03	8.20	6.75	7.27	1.88	3.05	2.92	2.72
Mean		1.69	2.61	2.16	2.16	5.23	5.19	5.96	5.46	1.42	1.61	1.95	1.66
Weighted mean		–	–	–	2.14	–	–	–	5.44	–	–	–	1.65
$NIR_{0.01}$		r.n.	0.40	0.36	–	2.23	r.n.	r.n.	–	r.n.	r.n.	r.n.	–

2-fold less calcium, and only the highest meal dose caused a significant increase in the calcium content of the first regrowth, compared with the control treatment.

Both grass quality and intake by animals are affected by sodium content. Sodium-deficient diets have to be supplemented with minerals. The sodium content of perennial ryegrass fertilized with higher doses of meat-and-bone meal in the first year, and with the highest dose in the second year was close to the value of 1.5–2.5 g Na kg^{-1} d.m. cited by FALKOWSKI et al. (2000). Sodium concentrations increased in successive regrowths in both years of the study. In the first year of the experiment, a meal dose of 0.5 and 1% contributed to a significant (approx. 4-fold) increase in the sodium content of perennial ryegrass, relative to the control. In the second year, plants fertilized with the highest dose of meat-and-bone meal accumulated the largest amounts of sodium, but the observed differences were statistically non-significant.

Conclusions

1. The results of the two-year experiment show that meat-and-bone meal applied pre-sowing in a single dose of 0.5% and 1% per pot caused an 11%

increase in the dry matter yield of perennial ryegrass, compared with the control treatment. The above doses satisfied the N and P demand of perennial ryegrass, while the lowest dose (0.25%) of meat-and-bone meal was insufficient to meet the nutrient requirements of plants in the second year of the study.

2. The highest dose of meat-and-bone meal contributed to a significant increase in the concentrations of nitrogen, potassium and sodium in perennial ryegrass, while the medium dose increased the levels of magnesium and calcium. The effect of increasing doses of meat-and-bone meal on the phosphorus content of the studied grass varied.

3. Meat-and-bone meal applied in a dose of 0.5% contributed to the most desirable mineral composition of perennial ryegrass, whereas the highest dose of meat-and-bone-meal resulted in excess accumulation of nitrogen and potassium in plants, thus inhibiting magnesium uptake.

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References

FALKOWSKI M., KUKUŁKA I., KOZŁOWSKI S. 2000. *Właściwości chemiczne roślin łąkowych*. Wyd. AR Poznań.

GÓRECKA H., SZTUDER H., SIENKIEWICZ-CHOLEWA. 2009. *Ocena przydatności rolniczej produktów nawozowych uzyskanych z utylizacji odpadów z produkcji zwierzęcej*. Zesz. Probl. Post. Nauk Roln., 537: 125–133.

JENG A.S., HARALDSEN T.K. VAGSTAD N., GRØNLUND N. 2004. *Meat and bone meal as nitrogen fertilizer to cereals in Norway*. Agric. food sci., 13: 268–275.

JENG A.S., HARALDSEN T.K., GRØNLUND A., PEDERSEN P.A. 2006. *Meat and bone meal as nitrogen and phosphorus fertilizer to cereals and rye grass*. Nutr. Cycl. Agroecosyst., 76: 183–191.

KOCHANOWSKA R., NOWAK W. 1992. *Zawartość makroskładników w niektórych gatunkach traw łąkowych*. Zesz. Nauk. AR w Szczecinie, Rolnictwo LII, 152: 13–21.

KRZYWY E., KRZYWY J., IŻEWSKA A. 2004. *Możliwość wykorzystania niektórych odpadów do wzbogacania gleb w fosfor*. Prace Naukowe AE Wrocław, Chemia. Związki fosforu w chemii, rolnictwie, medycynie i ochronie środowiska,1017: 221–229.

MAĆKOWIAK C. 2005. *Mączki mięsne na pola*. Top Agrar Polska, 3. http.//www.hurtmarket.com.pl/index.php?a=4&id=620568426, access: 2006.02.17

NOGALSKA A., CZAPLA J. 2009. *Wpływ zróżnicowanych dawek mączki mięsno-kostnej na wielkość i jakość plonu kostrzewy łąkowej*. Zesz. Probl. Post. Nauk Roln., 537: 263–272.

NOWAK W., DRASZAWKA-BOŁZAN B. 2001. *Zawartość makroelementów w życicy trwałej pod wpływem stosowania nawozów wieloskładnikowych*. Biul. Magnezol. 6(3): 310–315.

SPYCHAJ-FABISIAK E., KOZERA W., MAJCHERCZAK E., RALCEWICZ M., KNAPKOWSKI T. 2007. *Oddziaływanie odpadów organicznych i obornika na żyzność gleby lekkiej*. Acta Sci. Pol., Agricultura 6(3): 69–76.

STĘPIEŃ W., MERCIK S. 2002. *Ocena wartosci nawozowej odpadów przetwórstwa zwierzęcego*. Zesz. Probl. Post. Nauk Roln., 484: 595–600.

WOŁOSZYK C., KRZYWY E. 1999. *Badania nad rolniczym wykorzystaniem osadów ściekowych z oczyszczalni komunalnych w Goleniowie i Nowogardzie*. II. *Skład chemiczny życicy trwałej nawożonej osadami i kompostami z osadów ściekowych*. Fol. Univ. Agric. Stetin. Agricultura (77): 393–398.