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YIELD AND SELECTED INDICES OF GRAIN QUALITY IN SPRING WHEAT (*TRITICUM AESTIVUM* L.) DEPENDING ON FERTILIZATION

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Abstract

The aim of the research was to determine the effect of fertilization with manure, compost from biodegradable waste, and municipal sewage sludge on the yield and certain indices of grain quality in spring wheat in comparison to fertilization with mineral fertilizers. The research was conducted as a three-year field experiment. The limited access of plants to nutrients (mainly nitrogen) introduced with waste organic materials and with manure strongly affected the crop yield and its quality, particularly in the first year of the research. The residual effect of fertilization with pig manure and compost from biodegradable waste on the spring wheat grain yield was much better than that of fertilization with municipal sewage sludge. Fertilization with waste organic materials, in doses based on plant requirements for nutrients, did not lead to a decrease in the biological value of yield. Irrespective of the applied fertilization, copper and manganese were the microelements that limited the fodder value of spring wheat grain, whereas the quality of protein was determined by the content of lysine.

Key words: spring wheat, microelements, exogenous amino acids.

PLON I WYBRANE WSKAŹNIKI JAKOŚCI ZIARNA PSZENICY JAREJ (*TRITICUM AESTIVUM* L.) W ZALEŻNOŚCI OD NAWOŻENIA

Abstrakt

Celem badań było określenie wpływu nawożenia obornikiem, kompostem z odpadów biodegradowalnych oraz komunalnym osadem ściekowym na plon i niektóre wskaźniki jakości ziarna pszenicy jarej, w porównaniu z nawożeniem nawozami mineralnymi. Badania

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prowadzono w warunkach doświadczenia polowego przez 3 lata. Ograniczony dostęp roślin do składników pokarmowych (głównie azotu) wprowadzonych z materiałami organicznymi pochodzenia odpadowego oraz z obornikiem w znacznym stopniu determinował wielkość i jakość plonów, zwłaszcza w pierwszym roku badań. Stwierdzono istotnie lepszy, następczy wpływ nawożenia obornikiem od trzody chlewnej oraz kompostem z odpadów biodegradowalnych na plon ziarna pszenicy jarej w porównaniu z nawożeniem komunalnym osadem ściekowym. Nawożenie materiałami organicznymi pochodzenia odpadowego, w dawkach zgodnych z zapotrzebowaniem roślin na składniki pokarmowe, nie spowodowało pogorszenia wartości biologicznej plonu. Niezależnie od zastosowanego nawożenia, mikroelementami ograniczającymi wartość paszową ziarna pszenicy jarej były miedź i mangan, natomiast jakość białka była determinowana zawartością lizyny.

Słowa kluczowe: pszenica jara, mikroelementy, aminokwasy egzogenne.

INTRODUCTION

Wheat plays an important role in human nutrition and has a high yielding potential, which makes it one of the most popular crops not only in Poland, but also worldwide. Globally, about 60% of grain production is used for nutrition. The technological value of wheat grain is, to the greatest extent, conditioned by genetics. However, environmental and agrotechnical conditions are also significantly important (SIELING et al. 2005, CIU et al. 2006).

When analyzing the abundance of Polish soils in nutrients and humus, and in respect of acidification, signs of degradation of these soils are increasingly more frequent. It is mainly a result of insufficient amounts of natural, organic and also calcium fertilizers introduced to soil. The annual export of biogenic components with plant yields and losses of these components necessitates fertilization, regulating amounts of nutrients required by plants.

Adequate amounts of nutrients supplied to crops, alongside ensuring optimal soil conditions, are the main factors securing the expected yield with an adquate biological and technological value; at the same time they may determine doses of applied manure, compost or sewage sludge.

Cereal grain contains varied quantities of mineral components such as microelements, and organic components, including amino acids. In respect of nutrition, not all microelements or amino acids are equally important. Most often, the biological value of cereal grain is limited by the content of zinc, copper or manganese; among amino acids the limiting role is attributed to lysine and sulfur amino acids. The content of these elements and compounds may be conditioned by fertilization (FLAETE et al. 2005).

The aim of the research was to determine the effect of fertilization with manure, compost from biodegradable waste, and municipal sewage sludge on the yield and certain indices of grain quality in spring wheat in comparison to fertilization with mineral fertilizers.

MATERIAL AND METHODS

The research was conducted as a field experiment located 10 km west of Krakow (49°59' N; 19°41' E). Data from the meteorological station are presented in Table 1. Soil from the experimental site was classified to Stagnic Gleysol (IUSS Working Group WRB 2006). Table 2 presents selected soil properties prior to the research.

Table 1

Monthly rainfall and average daily temperature at the site in 2005-2007 and long-term mean (1961-1999)

Month	Sum of monthly precipitation (mm)				Monthly average temperature (°C)			
	2005	2006	2007	mean 1961-1999	2005	2006	2007	mean 1961-1999
January	66	58	101	34	-1.2	-2.4	3.2	-3.3
February	33	49	42	32	-4.3	-3.0	1.2	-1.6
March	21	60	61	34	-0.2	0.2	6.0	2.4
April	49	57	15	48	6.8	5.6	8.5	7.9
May	61	52	52	83	11.4	10.9	15.2	13.1
June	41	89	72	97	14.4	15.0	18.4	16.2
July	113	14	71	85	17.6	18.6	19.4	17.5
August	103	104	76	87	15.4	15.6	19.0	16.9
September	27	17	180	54	12.5	13.4	12.4	13.1
October	8	32	48	46	7.1	9.1	7.7	8.3
November	30	21	90	45	3.9	6.3	0.8	3.2
December	47	16	21	41	-0.7	0.9	-1.1	-1.0

The experiment was set up with the randomized block method. The plot area was 30 m^2. The experimental design comprised 5 treatments in four replications: without fertilization (0), fertilization with mineral fertilizers – MF (110.0 kg N ha^{-1}, 58.6 kg P ha^{-1} and 120.0 kg K ha^{-1}), fertilization with pig manure – PM (dose of 3.23 t ha^{-1} d.m.), fertilization with compost from biodegradable waste – C (dose of 2.83 t ha^{-1} d.m.) and fertilization with municipal sewage sludge – SS (dose of 2.65 t ha^{-1} d.m.).

The field was limed before setting up the experiment (autumn 2004). The liming was conducted according to $^1/_2$ hydrolytic acidity value (962.0 kg CaO ha^{-1}) In the spring of the subsequent year, after basic cultivation meas-

Table 2

Physical and chemical properties of the soil before experiment
(0-20 cm layer)

Determination	Unit	Value
pH (KCl)	-	5.60
Organic C	g kg^{-1} d.m.	15.3
Total N	g kg^{-1} d.m.	1.59
Total Cu	mg kg^{-1} d.m.	15.8
Total Zn	mg kg^{-1} d.m.	132.8
Total Mn	mg kg^{-1} d.m.	2230
P available	mg kg^{-1} d.m.	71.8
K available	mg kg^{-1} d.m.	297.5
Mg available	mg kg^{-1} d.m.	367.7
Bulk density	g cm^{-3}	1.52
Total porosity	cm^3 cm^{-3}	0.41
Fraction < 0.02 mm	g kg^{-1} d.m.	520

ures, manure, compost and sewage sludge were evenly spread over the surface of the plots and ploughed in. Two weeks later, supplementary mineral fertilization was applied; the fertilizers were mixed with the soil using a cultivator/harrow aggregate. The nitrogen dose supplied with organic materials was 110.0 kg N ha^{-1}. Phosphorus and potassium were supplemented with mineral fertilizers to an equal level in all treatments (except the control), [phosphorus to 58.6 kg P ha^{-1} as single superphosphate, and potassium to 120.0 kg K ha^{-1} as 60% potassium salt]. In the second and third year of the experiment, the same doses of components as in the first year were used, but only in the form of mineral fertilizers.

The test plant was spring wheat cv. Jagna, sown at the density of 485 plants per 1 m^2. Herbicides and fungicides were applied during the vegetative season to protect the field against weeds and fungal diseases.

The duration of a wheat growing period in each years depended on the weather conditions. Wheat was harvested at grain maturity: on 13 August 2005 in the first year of the research, on 3 August 2006 in the second year, and on 31 July 2007 in the third year. In order to determine the wheat yield under field conditions, the plants were harvested from an area of 4 m^2, separately from each plot.

Manure used in the research came from pigs that prior to its use had been stored on a manure pad for 6 months. The compost was made from plant waste and other biodegradable waste using the Mut-Kyberferm technology, in the following proportions: 25% grass, 20% wood chips, 20% leaves, 10% organic waste from market squares, 5% tobacco dust, and 20% waste from coffee production. The compost originated from a composting plant located in the city of Krakow. Stabilized sewage sludge (SS) came from a municipal biological sewage treatment plant located in the Czernichów commune (Malopolska region).

The following assessments were made on fresh samples of manure, compost and sewage sludge: dry mass content (at 105°C for 12 h), pH by potentiometer, electrolytic conductivity with a conductometer, total nitrogen content by the Kjeldahl's method. The content of organic matter and ash components was determined in dried and ground material after sample mineralization in a chamber furnace (at 450° C for 5 h). The phosphorus content was determined by colorimetry on a Beckman DU 640 spectrophotometer, and the potassium content was assayed by flame emission spectroscopy (FES) on a Philips PU 9100X apparatus. The concentrations of copper, zinc and manganese were determined by the ICP-AES method on a JY 238 Ultrace apparatus. The analyses were performed according to the methodology described in papers by Baran and Turski (1996), and Krzywy (1999), and the analytical results are presented in Table 3.

Table 3

Physical and chemical properties of the organic materials

Determination	Unit	Pig manure (PM)	Compost (C)	Sewage sludge (SS)
N_{tot}	g kg^{-1} d.m.**	34.0	38.9	41.6
P_{tot}	g kg^{-1} d.m.	12.8	5.9	22.3
K_{tot}	g kg^{-1} d.m.	21.8	29.9	1.2
C_{utot}	mg kg^{-1} d.m.	156	34	80
Z_{ntot}	mg kg^{-1} d.m.	284	194	950
M_{ntot}	mg kg^{-1} d.m.	355	280	112
EC*	mS cm^{-1}	2.89	2.62	0.47
pH (H_2O)		8.23	7.31	6.57
Organic matter	g kg^{-1} d.m.	831	531	726
Water content	g kg^{-1} f.m.***	774	563	742
Ash	g kg^{-1} d.m.	169	469	244

*EC – electrical conductivity, ** data are based on 105°C dry matter weight,
*** f.m. – fresh matter

The content of selected microelements was determined in dried and ground wheat grain after sample mineralization in a chamber furnace – 450°C, 5 h (Ostrowska et al. 1991) by the ICP-AES method on a JY 238 Ultrace apparatus.

Concentrations of selected amino acid were assessed in an AAA-400 (Ingos) analyzer following protein hydrolysis in 6 mol dm^{-3} HCl (110°C, 24 h). The methionine content was determined after oxidation with formic acid.

On the basis of the results, the index of limiting amino acid CS (the Chemical Score) designed by Block and Mitchell (Bęza 1967) was computed, which consisted in determining the ratio of the content of exogenous limiting amino acid in the analyzed protein to the content of the same amino acid in standard protein. Two standards were used for the calculations: mature human protein (MH) and whole egg protein (WE) (FAO/WHO 1991).

The analysis of the plant material was conducted in four replications. The precision of the Zn, Cu and Mn determinations was determined with the reference material NCS DC733448 (China National Analysis Center for Iron & Steel). The data on the precision and accuracy of the performed determinations are presented in Table 4 (Fuentes et al. 2004).

A two-way analysis of variance (factors: fertilization x years) was conducted for spring wheat grain yield, and a one-way analysis of variance (factor: fertilization) in a completely randomized design using f-Fisher test was conducted for weighted mean (from 3 years) content of the microelements, protein and exogenous amino acids. The significance of differences between arithmetic means was verified on the basis of homogenous groups determined by the Duncan's test at the significance level $p < 0.05$. All statistical computations were conducted using the Statistica PL package (Stanisz 1998).

Table 4

Amounts (mean ± SD) of metals released for material NCS DC733448, as well as data for analytical precision and accuracy

Metal	The value obtained in current study (mg kg^{-1} d.m.)	Recommended value (mg kg^{-1} d.m.)	Precision	Accuracy
Zn	21.4±1.0	20.6±2.2	4.71	3.88
Cu	5.3±0.1	5.2±0.5	1.88	1.92
Mn	55±1	58±6	1.82	5.45

RESULTS

Grain yields

On the plots where pig manure (PF), compost from biodegradable waste (C) and municipal sewage sludge (SS) were applied, spring wheat grain yields in the first year of the research were smaller by, respectively, 0.95 t, 1.23 t, and 0.56 t d.m. ha^{-1} in comparison to the yield from the treatment fertilized with mineral fertilizers (MF) – Table 5. The statistical analysis of the results confirmed significance of the differences between arithmetic means from individual treatments.

Table 5

Dry-matter yields of grain spring wheat for different year of experiment

Year	Treatments				
	0	MF	PM	C	SS
	t d.m. ha^{-1}				
2005	2.53^{b} ± 0.13	4.30^{ef} ± 0.23	3.35^{c} ± 0.16	3.07^{bc} ± 0.31	3.74^{c} ± 0.25
2006	2.00^{a} ± 0.18	4.97^{hi} ± 0.26	4.44^{efg} ± 0.27	4.31^{ef} ± 0.30	4.86^{gh} ± 0.30
2007	2.54^{b} ± 0.10	4.30^{ef} ± 0.35	5.39^{i} ± 0.31	5.41^{i} ± 0.11	4.42^{efg} ± 0.11

Means ± standard error. Different letters in columns indicate significant differences ($\alpha < 0.05$, Duncan's multiple range test)

In the second year, much smaller differences in wheat grain yields were found. The difference between the lowest grain yield, obtained after the application of compost from biodegradable waste (C), and the highest grain yield, obtained after fertilization with mineral fertilizers (MF), was 0.66 t d.m. ha^{-1}.

In the third year, higher spring wheat grain yields were gathered from the treatments where pig manure (PF), compost (C) and municipal sewage sludge (SS) were applied in the first year, in comparison to yields from the treatment where wheat was fertilized exclusively with mineral fertilizers (MF). The results indicate a much better residual effect of fertilization with pig manure (PM) and compost from biodegradable waste (C) on the spring wheat grain yield in comparison to fertilization with municipal sewage sludge (SS).

Content of microelements in grain

The zinc content in spring wheat grain varied depending on the applied fertilization (Table 6). The lowest content of this element was obtained in wheat grain from the treatment fertilized with pig manure (SM), whereas the highest amount of zinc was found in wheat grain from the treatment where only mineral fertilizers were used (MF).

No significant differences in the content of copper in spring wheat grain after fertilization were found (Table 6). The weighted mean content of Cu was within the range from 3.26 mg kg^{-1} d.m. (grain from the treatment where municipal sewage sludge was used) to 3.61 mg kg^{-1} 1 d.m. (grain from the unfertilized treatment).

Among the fertilized treatments, the highest content of manganese, was determined in grain of wheat fertilized with mineral fertilizers (MF) and after the application of compost from biodegradable waste (C) – Table 6 .

Table 6

Content of zinc, copper and manganese in grain of spring wheat

Treatments	mg kg^{-1} d.m.			
Fertilizer	year	Zn	Cu	Mn
0	1st	41.1	4.56	30.7
	3rd	51.3	2.58	17.7
	average*	49.7^{b} ± 4.02	3.61^{a} ± 0.51	27.9^{a} ± 4.60
MF	1st	48.4	4.68	28.1
	3rd	53.0	3.57	23.4
	average*	51.7^{b} ± 1.68	3.37^{a} ± 0.72	28.3^{a} ± 2.49
PM	1st	34.1	4.11	23.9
	3rd	45.8	4.76	16.0
	average*	43.1^{a} ± 3.99	3.35^{a} ± 0.96	24.9^{a} ± 4.73
C	1st	36.8	4.28	32.1
	3rd	47.5	4.63	18.1
	average*	45.9^{ab} ± 4.59	3.57^{a} ± 0.77	27.2^{a} ± 4.59
SS	1st	35.1	3.92	27.4
	3rd	52.3	4.16	14.9
	average*	46.0^{ab} ± 4.81	3.26^{a} ± 0.71	24.7^{a} ± 4.37

* average of three years ± standard error. Different letters in columns indicate significant differences ($\alpha < 0.05$, Duncan's multiple range test)

Content of protein and exogenous amino acids in grain

The total protein content was significantly higher in wheat grain from fertilized treatments in comparison to the protein content in unfertilized wheat grain (Table 7). The highest weighted mean content of total protein was found in grain of wheat fertilized with mineral fertilizers (MF).

Table 7

Content and selected indicators of the quality of grain protein of spring wheat

Treatments		Total protein (g kg^{-1} d.m.)	Σ EAA (g 100 g^{-1} protein)	CS (WE)$_{Lys}$	CS (MH)$_{Lys}$
Fertilizer	year				
0	1st	125.9	25.60	35.94	50.32
	3rd	162.9	22.12	40.22	56.31
	average*	142.8^a ± 9.38	25.2^a ± 1.34	31.3b^c ± 1.67	39.8^{bc} ± 2.13
MF	1st	153.7	26.33	42.63	59.68
	3rd	173.3	24.27	45.56	63.78
	average*	159.6^b ± 6.1	26.2^a ± 1.03	31.6^c ± 0.99	40.2^c ± 1.53
PM	1st	129.8	26.37	37.92	53.09
	3rd	176.0	22.26	43.42	60.79
	average*	154.6^b ± 11.7	25.1^a ± 1.28	31.1^b ± 1.58	39.6^b ± 2.02
C	1st	118.5	37.64	46.80	65.50
	3rd	174.3	23.35	42.11	59.00
	average*	149.6^{ab} ± 14.4	27.6^b ± 1.21	32.3^c ± 1.65	41.1^c ± 1.91
SS	1st	130.8	25.66	37.08	51.91
	3rd	184.3	20.72	41.40	57.95
	average*	157.8^b ± 13.5	24.0^a ± 1.44	29.3^a ± 1.75	37.3^a ± 2.23

CS – chemical score of restrictive amino acid; WE – whole egg protein standards;
MH – mature human
* average of three years ± standard error. Different letters in columns indicate significant differences (α < 0.05, Duncan's multiple range test)

The highest weighted mean content of exogenous amino acids (Σ EAA) occurred in wheat grain from the treatment where fertilization with compost from biodegradable waste was applied (27.6 g 100 g^{-1} of protein) – Table 7. On treatments fertilized with pig manure (PM), municipal sewage sludge (SS) and mineral fertilizers (MF), the weighted mean content of amino acids was significantly lower, respectively by 9.1%, 13.1%, and 5.1%.

The content of amino acids in wheat protein was much lower than in standard protein (Hidvégi, Békés 1984, FAO/WHO 1991). Lysine, methionine and threonine are amino acids that are highly deficient in fodders. Fertilization with compost from biodegradable waste generally increased the content of the examined exogenous amino acids the highest (except for the methionine content). In comparison to the amino acid composition of mature human protein or hen egg protein, it was concluded that lysine was the amino acid limiting spring wheat grain quality (Table 8).

Table 8

Composition of selected exogenous amino acids in protein of grain protein of spring wheat

Treatments		g 100 g^{-1} protein								
Ferti-lizer	year	Thr	Val	Ile	Leu	Phe	Lys	Met	His	Arg
0	1st	2.10	3.51	2.53	5.00	3.20	2.21	1.06	2.04	3.95
	3rd	1.87	2.87	2.06	4.31	2.76	1.90	0.61	1.71	3.52
	average*	2.14^{ab} ± 0.15	3.30^{a} ± 0.19	2.37^{ab} ± 0.14	4.96^{ab} ± 0.31	3.17^{ab} ± 0.20	2.19^{a} ± 0.14	0.71*a* ± 0.16	2.14*a* ± 0.05	4.04^{ab} ± 0.29
MF	1st	2.07	3.42	2.71	5.11	3.47	2.13	1.01	2.04	4.37
	3rd	2.01	3.10	2.34	4.76	3.17	2.03	0.66	1.88	4.09
	average*	2.19^{b} ± 0.14	3.37^{a} ± 0.14	2.55^{ab} ± 0.10	5.18^{b} ± 0.23	3.45^{b} ± 0.15	2.21^{a} ± 0.12	0.72^{a} ± 0.13	2.12^{a} ± 0.05	4.45^{b} ± 0.23
PM	1st	2.24	3.49	2.67	5.13	3.28	2.25	1.10	1.97	4.22
	3rd	1.89	2.89	2.32	3.69	2.90	1.91	0.65	1.71	3.70
	average*	2.17^{ab} ± 0.13	3.32^{a} ± 0.29	2.66^{b} ± 0.17	4.27^{a} ± 0.47	3.31^{ab} ± 0.22	2.18^{a} ± 0.13	0.76^{ab} ± 0.15	2.15^{a} ± 0.09	4.23^{ab} ± 0.29
C	1st	4.12	6.13	4.43	8.35	5.69	3.61	1.27	3.28	7.56
	3rd	3.57	5.30	3.86	7.63	5.10	3.24	1.10	2.92	6.56
	average*	2.49^{c} ± 0.43	3.70^{b} ± 0.65	2.69^{b} ± 0.46	5.29^{b} ± 0.77	3.55^{b} ± 0.55	2.26^{a} ± 0.35	0.76ab ± 0.13	2.30b ± 0.29	4.58^{b} ± 0.79
SS	1st	2.03	3.42	2.60	5.16	3.23	2.19	1.03	2.02	4.00
	3rd	1.71	2.57	1.91	4.01	2.64	1.73	0.60	1.58	3.32
	average*	2.01^{a} ± 0.15	3.05^{a} ± 0.22	2.27^{a} ± 0.18	4.75^{ab} ± 0.32	3.12^{a} ± 0.22	2.05^{a} ± 0.14	0.72^{a} ± 0.13	2.09^{a} ± 0.07	3.91^{a} ± 0.29

* average of three years ± standard error. Different letters in columns indicate significant differences ($\alpha < 0.05$, Duncan's multiple range test)

DISCUSSION

There is a wealth of research results indicating that it is possible to use organic waste material in biomass production (JAMIL et al. 2006, CARBONELL et al. 2011). The dynamics of biochemical processes occurring in soil, additionally intensified by environmental factors, may significantly affect the yield-forming efficiency of fertilization (STEWART, HASH 1982, BONDE et al. 1988) and the chemical composition of plants, including the content of microelements and exogenous amino acids (MALLARINO et al. 1999). In the first year of the research, the significantly lower wheat grain yield from treatments fertilized with organic materials resulted from the inhibited nutrient utilization by plants, particularly in the case of nitrogen, whose availability from organic materials depends on the weather conditions during the vegetative season, dose of applied fertilizer and the value of the carbon to nitrogen ratio (BARBARIKA et al. 1985, AGEHARA, WARNCKE 2004). Fertilization with organic materials makes it difficult to synchronize the amounts of N released from those materials with plant requirements for this component (MIKKELSEN, HARRTZ 2008). The research results clearly indicate that the depression in wheat grain yield in the first year of the research might have been caused by the spring term of organic materials application.

With time, the residual effect of organic materials becomes distinguishable, resulting in higher yields, the outcome that has been confirmed by our three-year scientific research. A beneficial effect of fertilization with sewage sludge and composted biodegradable waste on wheat biomass yield was also shown by TAMRABET et al. (2009), JAMIL et al. (2004), and BARZEGAR et al. (2002). However, IBRAHIM et al. (2008), while studying the effect of compost fertilization on wheat yield, drew attention to the need to balance amounts of nutrients supplied with fertilization.

The content of micronutrients in plant biomass is a product of the content of their assimilable forms in soil, which in turn is strongly modified by soil pH, organic matter content, soil sorption capacity as well as the cultivated plant species and fertilization (KOPEĆ, PRZETACZEK-KACZMARCZYK 2006). An insufficient content of copper, in terms of fodder quality, was found in our research. Apart from a lower fodder value of grain, a copper deficit also leads to limited amount and quality of yield, especially because copper is incorporated in many enzymes and proteins involved in specific metabolic processes (PRASAD 1995, YRUELA 2005). The soil reaction and content of organic matter, for which copper shows high affinity, are the factors limiting the availability of this element. According to GONDEK and KOPEĆ (2004), the formation of permanent bonds between humus and copper may cause low efficiency of soil fertilization with this element. The manure used in the research contained the most copper of the tested organic materials. Despite this, the copper concentration in spring wheat grain from plots fertilized with manure did not increase markedly. The results showed no significant effect of compost from biodegradable waste or municipal sewage sludge on the zinc and manganese concentrations in spring wheat grain in comparison to plants from the treatment fertilized with manure. It might have due to the relatively low content of these elements in the organic materials applied. The zinc content in grain was within the optimal range for animal nutrition, whereas the manganese content was deficient, regardless of the applied fertilization (MOLLER et al. 2000).

While using composts and municipal sewage sludge for fertilization, one may expect their beneficial effect on plant yield as well as its biological value. With respect to the chemical composition, which shapes the fodder nutritional value, it may be said that cereal grain is carbohydrate fodder with a low or medium content of total protein (BRAND et al. 2003). According to DUBETZ and GARDINER (1980), the content of protein and amino acids in wheat grain changes considerably under the influence of increasing doses of nitrogen. In our research, the nitrogen dose in all treatments (except the control) was the same, and the use of a dose of this element corresponding to the wheat's nutritional requirements, both in the form of mineral fertilizers and organic materials (manure, compost, sewage sludge), did not cause any significant changes in the content of the analyzed amino acids in the protein of spring wheat grain. Also according to JASIEWICZ and BARAN (2011), mineral fertilization diversifies the content of amino acids in plant biomass more than fertilization with organic materials. Cereal grain is usually low in lysine. Also in our experiment, lysine in grain was the amino acid that limited the protein quality with reference to both the whole egg protein standard (WE) and the mature human protein standard (MH), regardless of the applied fertilization. SHERRY (2007) obtained similar results in his research. The research results presented herein, however, are not confirmed by the research of JASIEWICZ and BARAN (2011), where it was found out that methionine was the amino acid limiting the protein quality in maize. The differences in the results may be attributable to the applied fertilization (type of organic material), the size of nitrogen dose and to the cultivated plant species. An adequate balance of the amino acid composition in food rations, matching the nutrient supply with animal requirements, is crucial, both because it enables optimal use of one of the most valuable nutrients, such as fodder protein, and because of the environmental aspect, such as a decrease in nitrogen excreted with urine whenever there is excess of each amino acid in relation to the demand.

CONCLUSIONS

1. The limited access of plants to mineral components (mainly nitrogen) introduced with organic waste materials and with manure determined the crop yield, particularly in the first year of the research.

2. A better residual effect of fertilization with pig manure and compost from biodegradable waste on the spring wheat grain yield was observed in comparison to fertilization with municipal sewage sludge.

3. Organic waste materials used in moderate doses based on the plant's requirements for nutrients did not decrease the biological value of yield.

4. Irrespective of the applied fertilization, copper and manganese were the microelements that limited the fodder value of spring wheat grain, whereas the quality of protein was determined by the content of lysine.

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