INFLUENCE OF FERTILIZATION WITH FERMENTED BIOSLUDGE ON THE YIELD AND NUTRITIVE VALUE OF ABOVEGROUND MAIZE (ZEA MAYS L.) PHYTOMASS

VPLYV HNOJENIA FERMENTOVANÝM BIOKALOM NA ÚRODU A VÝŽIVNÚ HODNOTU NADZEMNEJ FYTOMASY KUKURICE SIATEJ (ZEA MAYS L.)

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ABSTRACT

Yield and nutritional value of maize for silage in dependance on type, rate and application of organic manures were investigated in a field semi-operational experiment established near the biogas station in the location of Kolíňany in the years 2004 and 2005. The trial results confirmed a statistically high significant effect of weather conditions on the maize aboveground phytomass yield. Under the infavourable weather conditions of the year 2004 a lower yield (28.01 $t.ha^{-1}$) was achieved in comparison with the year 2005 (48.33 $t.ha^{-1}$). When 50 $t.ha^{-1}$ of biosludge was applied in autumn, the highest yield as well as the highest energy value of aboveground maize phytomass expressed in terms of net energy of lactation (NEL = 6.45 $MJ.kg^{-1}$ DM) and net energy of fattening (NEF = 6.47 $MJ.kg^{-1}$ DM) were achieved. Spring application of biosludge decreased the content of dry matter in maize by 20.7 %, and increased the content of crude protein by 13.7 %, crude fibre by 5.5 % and ash by 26.3 % compared to the values achieved at autumn biosludge application. The value of protein truly digested in the small intestine was the highest in treatment fertilized with farm - yard manure with the rate of 40 t. ha^{-1} (PDIN = 52.33 $g.kg^{-1}$ DM, PDIE = 77.37 $g.kg^{-1}$ DM).

Key words: maize, farm - yard manure, biosludge, yield, energy and protein value

ROZŠÍRENÝ ABSTRAKT

V poľnom poloprevádzkovom pokuse založenom v blízkosti bioplynovej stanice v lokalite Kolíňany sa sledovala v rokoch 2004 a 2005 úroda a výživná hodnota nadzemnej fytomasy kukurice siatej v závislosti od druhu, dávky a termínu aplikácie organických hnojív. Kukurica siata odrody ANIOU 450 sa pestovala na piesočnato-hlinitej hnedozemi so slabo kyslou pôdnou reakciou, stredným obsahom fosforu, dobrým obsahom draslíka, veľmi vysokým obsahom horčíka a malým obsahom humusu. Experimentálny pozemok je situovaný v kukuričnej výrobnej oblasti, v miernej klimatickej oblasti B 3 (mierne teplá, mierne vlhká) s nadmorskou výškou 192 m n. m. Dlhodobý úhrn zrážok (1951-1980) bol 561 mm, dlhodobá priemerná ročná teplota vzduchu bola 9,7 ^{0}C.

Pokus bol založený s piatimi variantmi hnojenia, ktoré boli štvornásobne opakované. Na variantoch hnojených organickými hnojivami sa aplikovalo kombinované priemyselné hnojivo NPK 15-15-15 v dávke 250 kg.ha^{-1}. Varianty hnojenia sú diferencované rozdielnymi dávkami organických hnojív: variant 1: nehnojená kontrola, variant 2: NPK + 25 t.ha^{-1} maštaľného hnoja (MH 25), variant 3: NPK + 50 t.ha^{-1} biokalu aplikovaného na jeseň (kal jeseň), variant 4: NPK + 40 t.ha^{-1} maštaľného hnoja (MH 40), variant 5: NPK + 50 t.ha^{-1} biokalu aplikovaného na jar (kal jar).

Výsledky pokusov potvrdili štatisticky vysoko preukazný vplyv pestovateľského ročníka na úrodu nadzemnej fytomasy kukurice siatej. V poveternostne nepriaznivom roku 2004 sa dosiahla nižšia priemerná úroda fytomasy (28,01 t.ha^{-1}) ako v roku 2005 (48,33 t.ha^{-1}). Aplikáciou biokalu na jeseň v dávke 50 t.ha^{-1} sa dosiahla najvyššia úroda (40,89 t.ha^{-1}) a najvyššia energetická hodnota nadzemnej fytomasy kukurice siatej, vyjadrená hodnotami netto energie laktácie (NEL = 6,45 MJ.kg^{-1}suš.) a netto energie výkrmu (NEV = 6,47 MJ.kg^{-1}suš.). Jarná aplikácia biokalu v porovnaní s aplikáciou biokalu na jeseň znížila obsah sušiny o 20,7 %, zvýšila obsah N- látok o 13,7 %, vlákniny o 5,5 % a popola o 26,3 %. Hodnota skutočne stráviteľných dusíkatých látok v tenkom čreve bola najvyššia na variante hnojenom maštaľným hnojom v dávke 40 t.ha^{-1} (PDIN = 52,33 g.kg^{-1} suš., PDIE = 77,37 g.kg^{-1} suš.).

Dusíkaté hodnoty na variantoch hnojených biokalom potvrdzujú, že so vzrastajúcou sušinou celých rastlín klesá koncentrácia dusíkatých látok, zatiaľ čo PDIN sa s narastajúcou sušinou znižuje, PDIE sa zvyšuje.

Kľúčové slová: kukurica siata, maštaľný hnoj, biokal, úroda, energetická a dusíkatá hodnota

INTRODUCTION

Silage maize is a significant glycide feed and source of nutrients in farm animals nutrition. Under appropriate harmonization of agroclimatic, soil and technological requirements, this crop can provide a high amount of organic matter by which it absorbs considerable quantity of nutrients from soil. By 10 tons of green mass it takes up 21 kg N, 4.3 kg P and 29 kg K [4]. Maize requires slow and permanent release of nutrients in soil. This need is ensured by organic manuring [5], particularly by farm - yard manure which as complex biofertilizer offers the whole spectra of positive effects on biological activity of soil, its physical properties and agrochemical characteristics [8]. As consequence of the reduction of farm animals numbers, production of farm manures decreased markedly in the Slovak Republic. Just for this reason utilization of various alternative forms of farm by products and wastes of organic character increasingly rises with the aim to decrease organic matter deficit in soil.

Continual anaerobic fermentation of animal and plant wastes in the process of biogas production provides as a by-product biosludge suitable for field crops fertilization. Utilization of biosludge for fertilizing purposes reduces the requirements of sugar beet and silage maize for mineral fertilizers [7] and improves organic matter balance [6]. Spring application of biosludge represents a source of available nitrogen for plants and enables to reach a positive balance of phosphorus and potassium resulting in their increased content in the soil. Application of biosludge also showed positive influence on the moisture regime in soil mainly by holding water in upper part of arable profile, infiltration ability of soil and structural aggregates formation [9]. Below - limit amounts of heavy metals in both biosludge and grown plants were determined [16].

The aim of this contribution is to characterize yield, energy parameters and nutrition value of the whole plant of maize (Zea mays L.) under the application of organic fertilizers in various rates and terms.

MATERIAL AND METHODS

A field small-plot experiment with maize (variety ANIOU 450) grown in crop rotation after sugar beet, was established on sandy-loam brownsoil near to biogas station in the location of Kolíňany. The experimental site belongs to the maize productional region in moderate climatic region B3 (moderately warm, moderately wet) with an altitude of 192 m. The long term sum of annual precipitation (1951 - 1980) represents 561mm, the long term average annual atmospheric temperature is 9.7 °C.

Weather conditions during the experimental period are illustrated in fig. 1 and 2.

Agrochemical soil characteristics before the trial establishment are stated in table 1. The content of available nutrients in the soil was determined by the Mehlich III method.

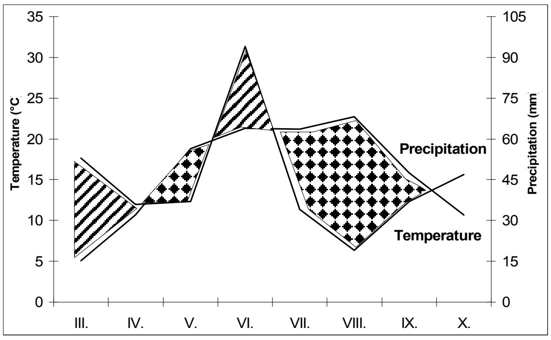

Figure 1: Pattern of weather conditions in year 2004
Obr. 1: Priebeh poveternostných podmienok v roku 2004 (1) vlhké obdobie, (2) suché obdobie

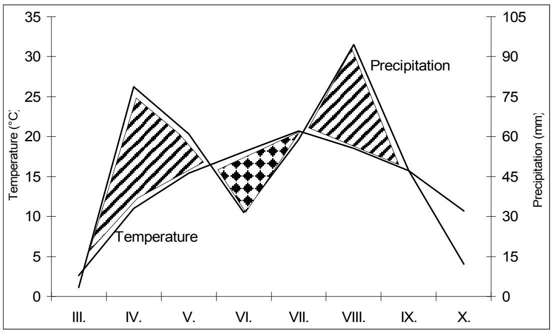

Figure 2: Pattern of weather conditions in year 2005
Obr. 2: Priebeh poveternostných podmienok v roku 2005

Five treatments of fertilization, each in four replications, were investigated in the experiment as follows:

treatment 1: unfertilized control

treatment 2: NPK 15-15-15 + 25 $t.ha^{-1}$ of farm - yard manure (FYM 25)

treatment 3: NPK 15-15-15 + 50 $t.ha^{-1}$ of biosludge applied in autumn (BSA)

treatment 4: NPK 15-15-15 + 40 $t.ha^{-1}$ of farm - yard manure (FYM 40)

treatment 5: NPK 15-15-15 + 50 $t.ha^{-1}$ of biosludge applied in spring (BSS)

In all treatments fertilized with organic manures, 250 $kg.ha^{-1}$ of the combined mineral fertilizer NPK 15-15-15 was applied in autumn.

The results of chemical analysis of applied organic fertilizers are stated in table 2.

Average samples of fresh plant material were taken from each treatment, contents of nutrients were determined [11] and energy and nitrogen values were calculated [12].

RESULTS AND DISCUSSION

Yield of aboveground silage maize phytomass and its nutritive value were influenced by the course of weather conditions and organic manures application; however not only by the kind of organic fertilizer, but also by its quality (content of nutrients), rate and term of application as well (table 3).

On the average of two experimental years, average yield of 38.17 $t.ha^{-1}$ was achieved. The effect of weather conditions on the maize yield was highly significant. More favourable temperature and moisture conditions in 2005, particularly the sufficiency of precipitation in July and August showed a positive effect on yield formation (48.33 $t.ha^{-1}$). Lower yield in 2004 (28.01 $t.ha^{-1}$) was caused by precipitation deficit during the emerging of seedlings and quick increase of dry matter in July and August. Concretly, in July the precipitation achieved was only 40 % of the 40-years precipitation normal, in August only 33 % (19 mm). Karabínová et al. [10] state, that the amount of precipitation for successful maize growing should reach 100 - 120 mm in July and 70 - 80 mm in August.

In consequence of the fertilization, yield of maize aboveground biomass increased significantly by 7.62 $t.ha^{-1}$ (BSS) and 10.18 $t.ha^{-1}$ (BSA), that is by 24.8 % and 33.1 %, respectively.

In maize nutrition nitrogen has a dominant position. It increases yield, content of crude protein, fibre and ash [1, 3].

Table 1: Agrochemical soil analysis
Tabuľka 1: Agrochemický rozbor pôdy

Year	P	K	Mg	pH_{KCl}	Humus
		$mg.kg^{-1}$			%
2004	55	208	392	6,25	1,76
2005	81	204	360	6,22	1,79

Table 2: Analysis of organic manures
Tabuľka 2: Rozbor organických hnojív

Organic manure (1)	Experimental year (2)	Content of nutrients (g.kg^{-1} DM) (3)				
		N	P	K	Ca	Mg
Farm-yard	2003/2004	16.8	3.2	23.2	34.2	4.1
manure (FYM) (4)	2004/2005	22.9	5.9	24.6	25.7	6.2
Biosludge autumn	2003/2004	33.2	8.7	39.4	46.9	15.2
(BSA) (5)	2004/2005	24.6	6.9	20.3	21.0	5.7
Biosludge	2003/2004	25.8	7.7	45.4	38.8	13.9
spring (BSS) (6)	2004/2005	16.6	5.6	27.1	17.5	6.1

(1) organické hnojivo, (2) pokusný rok, (3) obsah živín (g.kg^{-1} suš.), (4) maštaľný hnoj (MH), (5) biokal jeseň (kal jeseň), (6) biokal jar (kal jar)

As a source of nutrients, farm - yard manure releases nutrients during 2 - 3 years and the best utilization of nutrients is achieved, when mineral fertilizers are applied at the same time. In treatment FYM 40, the input of nitrogen was the highest, reaching 239 kg.ha^{-1}. Dry matter yield decreased by 5.5. % and crude protein content increased by 24.5 % in comparison with control, what corresponds with results stated by Múdry et al. [13].

Content of ash increased by 12 % compared to the unfertilized control and the content of organic matter decreased by 0.6 % at the same time. There was not confirmed negative correlation between graduated N-rates and the content of ash [2].

Quality of biosludge which was applied in years 2003/2004 and 2004/2005 was different. Various nutrient content in biosludges was caused by the variability of materials entering the biogas unit. The amount of fundamental nutrients (N, P, K) applied into the soil through the biosludge was significantly influenced by its dry matter. Biosludge of very good quality was produced in the year 2004/2005.

When biosludge was applied in autumn (input of N in the form of fertilizers = 132 kg.ha^{-1} on the average of two experimental years) the highest DM content in maize aboveground biomass (294.3 g.kg^{-1} DM) was determined and a decline of CP, fibre and ash content was registered. In comparison with the unfertilized treatment, the content of nitrogen free extract (NFE) and organic matter content increased by 7.7 % and 0.7 %, respectively.

Spring biosludge application (input of N in the form of fertilizers = 95 kg.ha^{-1}) decreased the DM content in aboveground maize biomass by 20.7 % and increased CP content by 13.7 %, fibre content by 5.5 % and ash content by 26.3 %. Content of nitrogen free extract as well as organic matter were decreased.

The highest energy value of aboveground maize phytomass, expressed in terms of net energy of lactation (NEL = 6.45 MJ.kg^{-1} DM) and net energy of fattening (NEF = 6.47 MJ.kg^{-1} DM), was found with a biosludge autumn application at the rate of 50 t.ha^{-1}, what is in accordance with results stated by Pospišil and Mano [14]. The value of NEL and NEF were higher by 1.4 and 1.6 %, respectively in comparison with treatment FYM 40.

Uptake of nitrogen substances was evaluated according to protein truly digested in the small intestine (PDI). Limiting fraction of PDI in maize appears to be PDIN (ingested digestive protein allowed by energy). Higher values of PDIN were found in treatments fertilized with farm - yard manure, when at 40 t.ha^{-1} of FYM PDIN achieved 52.33 g.kg^{-1} DM. PDIN values were lower by 7.01 g.kg^{-1} DM (BSS) and 12.48 g.kg^{-1} DM (BSA), respectively in treatments fertilized by biosludge.

The highest value of PDIE (ingested digestive protein allowed by nitrogen) was determined with the treatment FYM 40 (77.37 g.kg^{-1} DM), the lowest one in the control treatment (74.48 g.kg^{-1} DM). Šuk et al. [15] state that with increasing DM content in aboveground maize phytomass, the content of CP decreases and both PDIN and PDIE values increase. The values of PDIE in treatments fertilized by biosludge confirm these findings.

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REFERENCES

[1] AMARAL J.P.R., FORNASIERI D., FARINELLI R., BARBOSA J.C., Row spacing, population density and nitrogen fertilization in maize, Revista Brasileira de Ciencia do Solo, (2005) 29: 467-473.

[2] BARAN M., Vplyv stupňovaných dávok

Table 3: Content of nutrients, energy and nitrogen value and yield of maize
Tabuľka 3: Obsah živín, energetická a dusíkatá hodnota a úroda kukurice siatej

Parameter		Control (19)			FYM 25 (20)			BSA (21)			FYM 40 (22)			BSS (23)		
		2004	2005	$\overline{x}$	2004	2005	$\overline{x}$	2004	2005	$\overline{x}$	2004	2005	$\overline{x}$	2004	2005	$\overline{x}$
Content ($g.kg^{-1}$ fresh matter) ($g.kg^{-1}$ dry matter) (1)	DM (4)	324.7	250.4	287.6	320.9	265.2	293.1	317.8	270.8	294.3	292.1	251.5	271.8	284.0	183.0	233.5
	CP (5)	62.2	63.3	62.8	85.3	79.6	82.5	63.5	65.2	64.4	72.0	84.4	78.2	71.5	74.9	73.2
	Fat (6)	14.7	25.1	19.9	15.6	25.3	20.5	16.0	23.9	20.0	10.9	25.1	18.0	11.1	31.0	21.1
	Crude fiber (7)	230.4	253.9	242.2	164.6	255.2	209.9	185.2	212.2	198.7	226.9	235.1	231.0	220.5	198.7	209.6
	Ash (8)	53.6	35.0	44.3	50.8	48.9	49.9	35.3	39.3	37.3	52.9	46.3	49.6	38.8	55.4	47.1
	NFE (9)	639.1	622.7	630.9	683.7	591.0	637.4	700.0	659.4	679.7	637.3	609.1	623.2	658.1	640.0	649.1
	Organic matter (10)	946.4	965.0	955.7	949.2	951.1	950.2	964.7	960.7	962.7	947.1	953.7	950.4	961.2	944.6	952.9
Energy value (2) $MJ.kg^{-1}$ DM	NEL (11)	6.34	6.46	6.40	6.33	6.37	6.35	6.46	6.44	6.45	6.34	6.38	6.36	6.44	6.32	6.38
	NEF (12)	6.35	6.47	6.41	6.35	6.37	6.36	6.48	6.45	6.47	6.35	6.38	6.37	6.44	6.33	6.39
Nitrogen value (3) $g.kg^{-1}$ DM	PDIN (13)	38.51	39.19	38.85	52.81	49.27	51.04	39.32	40.37	39.85	52.41	52.25	52.33	44.27	46.37	45.32
	PDIE (14)	74.23	74.72	74.48	73.52	77.38	75.45	75.59	74.93	75.26	76.57	78.16	77.37	77.42	75.12	76.27
Yield (15) ($t.ha^{-1}$)		19.68	41.73	30.71	31.66	48.80	40.23	31.04	50.73	40.89	30.32	51.05	40.69	27.33	49.32	38.33

Treatments of fertilization (18)

years (16): $Hd_{0.05} = 5.2414$, $Hd_{0.01} = 7.0520$; treatments (17): $Hd_{0.05} = 8.2875$, $Hd_{0.01} = 11.1503$

(4) dry matter, (5) crude protein, (9) nitrogen free extract, (11) net energy of lactation, (12) net energy of fattening, (13) ingested digestive protein allowed by energy, (14) ingested digestive protein allowed by nitrogen

(1) obsah ($g.kg^{-1}$ čerstvej hmoty), ($g.kg^{-1}$ sušiny), (2) energetická hodnota, (3)dusíkatá hodnota, (4) sušina, (5) N- látky, (6) tuk, (7)vláknina, (8) popol (9) bezdusíkaté látky výťažkové, (10)organická hmota, (11) netto energia laktácie, (12) netto energia výkrmu, (13), (14) skutočne stráviteľné dusíkaté látky v tenkom čreve, (15) úroda, (16) roky, (17) varianty, (18) varianty hnojenia, (19) kontrola, (20) MH 25 - maštaľný hnoj v dávke 25 $t.ha^{-1}$, (21) kal jeseň - biokal aplikovaný na jeseň, (22) MH 40 - maštaľný hnoj v dávke 40 $t.ha^{-1}$, (23) kal jar - biokal aplikovaný na jar

dusíka na produkciu a nutričnú hodnotu miešanky kukurice a sóje, Poľnohospodárstvo, (1987) 37 (7-8): 615-627.

[3] BÍRO D., JURÁČEK M., GÁLIK B., ŠIMKO M., LOŽEK O., Vplyv stupňovaných dávok dusíka na výživnú hodnotu kukurice siatej (Zea mays, L.), Agriculture, (2006) 52 (2): 101-106

[4] BÍZIK J., FECENKO J., KOTVAS F., LOŽEK O., Metodika hnojenia a výživy rastlín, Bratislava: AT Publishing, 1998:112.

[5] DIVIŠ J., LONGAUEROVÁ J., Metodiky pro zavádění výsledků výzkumu do zemědělské praxe, Praha: ÚZPI, 1993: 22 .

[6] HANÁČKOVÁ E., Balance of soil organic matter under the application of fermented substrate as organic fertilizer, Humic Substances in Ecosystems, 6. Bratislava: VÚPOP, 2005: 72-76.

[7] HANÁČKOVÁ E., SLAMKA P., Balance of nutrients in crop rotation under the application of decayed sludge as organic fertilizer, Humic Substances in Ecosystems, 6, 2005, Bratislava: VÚPOP, 2005: 68-71.

[8] HLUŠEK J., Základy výživy a hnojení zeleniny a ovocných kultur, Praha: IVV MZ ČR, 1996: 48.

[9] IGAZ D., ŠIŠKA B., POSPIŠIL R., Zmena infiltračnej schopnosti pôdy vplyvom organického hnojenia pod porastom cukrovej repy, Acta horticulturae et regiotecturae, (2004) 7 (2): 44 - 47 .

[10] KARABÍNOVÁ M., MOLNÁROVÁ J., ŽEMBERY J., Obilniny III. Pestovanie kukurice, ciroku, prosa a pohánky, Kuriér + reklama, s.r.o., 2001: 91.

[11] MP SR, Výnos MP SR č. 1497/4/1997-100 o úradnom odbere vzoriek a o laboratórnom skúšaní a hodnotení krmív, in: Vestník MP SR, 30, 1998, part 11.

[12] MP SR, Príloha č. 8 k výnosu MP SR č. 39/1/2002-100 Výživná hodnota hospodárskych krmív, in: Vestník MP SR, 34, 2002, part 4.

[13] MÚDRY P., JURÁČEK Ľ., SEDLÁK A., Vplyv dávok dusíka, hustoty porastu a doplnkovej závlahy na modelový hybrid kukurice. I. Ukazovatele vegetatívneho rastu, Poľnohospodárstvo, (1996) 42 (9): 657-668.

[14] POSPIŠIL R., MANO M., Vplyv aplikácie biokalu na produkciu a kvalitu kukurice siatej na siláž. Súčasnosť a perspektívy krmovinárskeho výskumu a vzdelávania v multifunkčnom využívaní krajiny, Nitra: SPU, 2001:231-233.

15] ŠUK J. et al., Kukuřice. Praha: VP AGRO, s.r.o. Kněževes, 1998.

[16] TÓTH T., POSPIŠIL R,. PARILÁKOVÁ K., MUSILOVÁ J., BYSTRICKÁ J., Distribúcia ťažkých kovov v pôdach s aplikáciou substrátu po výrobe bioplynu. ChemZi., 57. zjazd chemických spoločností, 2005:108.