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IMPROVEMENT OF THE EFFECTIVENESS OF MAIZE (*Zea mays* L.) FERTILIZATION WITH NITROGEN BY THE APPLICATION OF MAGNESIUM PART II. CONTENT OF NUTRIENTS IN GRAIN AND ITS ENERGETIC VALUE

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Abstract. Field experiments were carried out at the Didactic and Experimental Farm in Swadzim (52°26' N; 16°45' E) near Poznań in the years 2004-2007. The experiment was carried out in a „split-plot" design with 3 experimental factors and 4 field replications. Two cultivars were studied, 6 doses of nitrogen, one dose of magnesium and the method of fertilizer application were investigated. The content of total protein and N-free extract in the dry matter of grain depends exclusively on the level of nitrogen fertilization. As far as ash content is concerned, it was found that the value of this feature depends only on the cultivar factor. The contents of raw fibre and raw fat were not determined by any of the experimental factors. A higher yield of total protein was obtained from the hybrid LG 2244 in comparison with Anjou 258. Analysis of the amount of nitrogen fertilization has shown that the significantly highest yield of protein was obtained for a dose of 90 kg $N \cdot ha^{-1}$. On the other hand, a further increase in nitrogen dose caused a significant breakdown of this feature value. Magnesium fertilization amount and the method of its application did not exert any effect on the yield of total protein. The concentration of net energy was not affected by any experimental factors, while the yield of grain net energy was determined by the amount of nitrogen fertilization. The yield of digestible protein depended in a significant way on the cultivar factor and on nitrogen fertilization.

Key words: fertilizer application method, magnesium, maize cultivar types, nitrogen

INTRODUCTION

Maize (*Zea mays* L.) is a plant with very high yield possibilities and the obtained biomass can be utilized in many different ways. Maize is a source of carbohydrate feeds with a high nutritive value. The growing of this plant in grain technology permits the

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farmer, depending on the method of grain harvesting, to obtain several feed types regarding their chemical composition and the application in the feeding of farm animals [Michalski 1997]. Maize grain is a feed with the highest concentration of nutrients useful in the production of concentrated feeds [Michalski 1997] because it contains almost all necessary nutritive components in an easily assimilable form [Sulewska and Ptaszyńska 2008].

The purpose of the present studies was to get acquainted with the effect of magnesium application method on the energetic value of the grain of two types of maize hybrids, depending on the level of nitrogen fertilization.

MATERIAL AND METHODS

An exact description of the methods of studies and of thermal and humidity conditions were contained in another author's paper [Szulc et al. 2008].

Analyses of organic component content in maize cobs were carried out in the Department of Soil and Plant Cultivation, University of Life Sciences in Poznań, according to the following methods: total protein was determined by the examination of nitrogen content in a sample using Kjeldahl's method and the result was multiplied by coefficient 6.25; fat was studied by Soxhlet's method; crude fibre was identified by the hydrolysis of the remaining components contained in the cob; ash was determined by dry combustion method; while nitrogen-free extracts were calculated by extraction of the remaining contents from the total 100% sum.

Evaluation of the energetic value of grain was done according to the method of Kellner by calculating oat units which were converted into net energy assuming that one oat unit = 7.6 MJ of net energy for pigs [Gawęcki 1994]. This permitted to determine the net energy concentration, the energy yield and the yield of digestible protein. The yield of protein was calculated by the multiplication of the proportional content of protein in the cobs by their yield.

RESULTS AND DISCUSSION

On the average, for the period of 3 years of studies, none of the studied experimental factors has affected in a significant way the content of crude fibre and crude fat (Table 1).

The cultivar factor played a role only in case of ash content. A higher value of this feature by about point 0.11% was obtained only for the hybrid LG 2244 (stay-green type) in comparison with the hybrid Anjou 258 (Table 1). Ash content in maize grain depended also on the interaction between cultivar and the dose of magnesium, as well as on the method of Mg application (Fig. 1). The content of ash for a dose of 0 kg $Mg \cdot ha^{-1}$, independently of the cultivar type, was statistically on the same level, while for a dose of 15 kg $Mg \cdot ha^{-1}$ applied by broadcasting and in rows it was significantly higher for the hybrid of stay-green type. The level of magnesium dose and the way of its application did not differentiate the values of this feature within the cultivars themselves.

In our own studies, the nitrogen fertilization level determined only the percentage of total protein and the nitrogen free extract (Table 1). Under the influence of the increasing level of nitrogen fertilization, the total protein content increased from 9.60% (0 kg $N \cdot ha^{-1}$) to 10.4% at the highest dose of nitrogen. As reported by Bruździak [1988],

in the phase of full maturity of grain about 60% of total protein is found in the grain. Maize protein, because of a low content of lysine and tryptophane, has a small biological value, but it is characterized by a good digestibility [Lipiński 2003]. Its content in the grain in different types of maize cultivars can oscillate between 6 and 21% and it is connected with a proportion of a glassy layer in the grain mass [Królikowski 2002]. Sulewska and Ptaszyńska [2008] reported that in maize, the protein content is more intensively formed by the course of weather conditions than by the genotype. Hence, in our own studies, no effect of cultivar factor on the value of this feature was found. On the other hand, Szmigiel et al. [2006], who studied the reaction of three maize hybrids to organic and mineral fertilization, showed a different content of protein in the grain depending on the kind of fertilizer and the hybrid type.

Table 1. Content of nutrients in grain
Tabela 2. Zawartość składników pokarmowych w ziarnie

Specification – Wyszczególnienie		In dry mass – W suchej masie, %				
		total protein białko ogólne	crude fibre włókno surowe	ash popiół	crude fat tłuszcz surowy	N-free extract związki bezazotowe wyciągowe
Cultivar Odmiana	Anjou 258	10.1	2.47	1.95	4.14	81.4
	LG 2244	10.1	2.37	2.06	4.36	81.1
	$LSD_{0.05}$ – $NIR_{0,05}$	ns – ni	ns – ni	0.021	ns – ni	ns – ni
Dose of N Dawka N kg·ha^{-1}	0	9.60	2.33	1.98	4.33	81.8
	30	9.90	2.41	2.04	4.37	81.2
	60	10.0	2.44	2.01	4.24	81.3
	90	10.2	2.45	1.95	4.18	81.2
	120	10.3	2.42	2.02	4.24	81.0
	150	10.4	2.48	2.02	4.13	80.9
	$LSD_{0.05}$ – $NIR_{0,05}$	0.34	n.s.	.n.s.	n.s.	0.265
Dose of Mg Dawka Mg kg·ha^{-1}	0	10.0	2.41	1.99	4.26	81.3
	15 in rows – rzędowo	10.1	2.42	2.02	4.27	81.2
	15 broadcasting – rzutowo	10.1	2.43	1.99	4.21	81.3
	$LSD_{0.05}$ – $NIR_{0,05}$	ns – ni	ns – ni	ns – ni	ns – ni	ns – ni

ns – ni – non significant differences – różnice nieistotne

The content of nitrogen free extract decreased under the influence of an increasing level of nitrogen fertilization from 81.8% (0 kg N·ha^{-1}) to 80.9% (150 kg N·ha^{-1}) (Table 1). The results obtained in our own studies are also confirmed by Kruczek [2004]. That author fertilized maize with nitrogen in the dose range from 25 kg N·ha^{-1} to 130 kg N·ha^{-1} and obtained an increase in the percentage of protein and a decrease in nitrogen free extract in the grain under the influence of the increasing fertilization level. The dose of magnesium and the method of its application did not differentiate the content of total protein, crude fibre, ash, crude fat and nitrogen free extract.

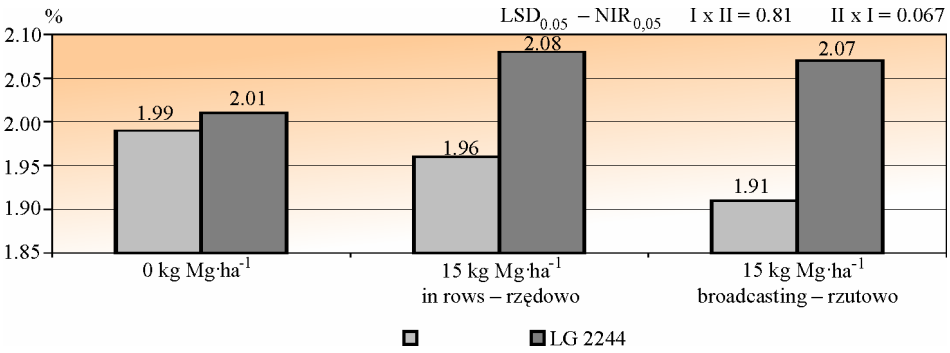

Fig. 1. Ash content in grain depending on the cultivar and on magnesium application method
Rys. 1. Zawartość popiołu w ziarnie w zależności od odmiany i sposobu wysiewu nawozu magnezowego

The energetic value of maize grain expressed by net energy concentration was not modified by any of the studied experimental factors (Table 2). The net energy yield depended in a significant way only on the nitrogen fertilization level. The highest value of this feature was obtained by the application of nitrogen fertilization of maize in a dose of 90 kg N·ha^{-1} and it was higher by 11.2 GJ·ha^{-1}, in comparison with the yields from treatments without nitrogen fertilization. The application of a nitrogen dose of 150 kg N·ha^{-1} caused a significant decrease in net energy yield in comparison with treatments fertilized with a dose of 90 kg N·ha^{-1}. Kruczek [2004], in turn, in his studies did not show any effects of the level of nitrogen fertilization on the net energy yield of grain.

Table 2. Net energy concentration, net energy yield, protein yield and digestible protein yield in grain
Tabela 2. Koncentracja i plon energii netto, plon białka i białka strawnego w ziarnie

	Specification Wyszczególnienie	Net energy concentration Koncentracja energii netto	Net energy yield Plon energii netto	Digestible protein yield Plon białka strawnego	Protein total yield Plon białka ogólnego
		MJ·kg^{-1} dm – s.m.	GJ·ha^{-1}	t·ha^{-1}	
Cultivar Odmiana	Anjou 258	10.0	103.3	0.79	0.88
	LG 2244	10.0	110.3	0.84	0.94
	$LSD_{0.05} – NIR_{0.05}$	ns – ni	ns – ni	0.050	0.564
Dose of N Dawka N kg·ha^{-1}	0	10.0	100.5	0.73	0.81
	30	10.0	107.7	0.81	0.91
	60	10.0	106.8	0.81	0.91
	90	10.0	111.7	0.87	0.97
	120	10.0	108.8	0.85	0.95
	150	9.99	105.5	0.83	0.93
	$LSD_{0.05} – NIR_{0.05}$	ns – ni	5.181	0.055	0.335
Dose of Mg Dawka Mg kg·ha^{-1}	0	10.0	107.5	0.81	0.91
	15 in rows – rzędowo	10.0	106.3	0.81	0.91
	15 broadcasting – rzutowo	10.0	106.8	0.81	0.91
	$LSD_{0.05} – NIR_{0.05}$	ns – ni	ns – ni	ns – ni	ns – ni

ns – ni – non significant differences – różnice nieistotne

The yield of protein and the yield of digestible protein for the period of three years of studies depended on the average on the cultivar type and on the level of nitrogen fertilization (Table 2). Higher yields of protein and digestible protein were obtained for the hybrid LG 2244 (stay-green type), as compared with the Anjou 258 cv. These differences amounted to 0.06 t·ha^{-1} and 0.05 t·ha^{-1}, respectively. The highest yields of protein and digestible protein were obtained in treatments fertilized with the doses: 90 kg N·ha^{-1} (0.97 t·ha^{-1} and 0.870 t·ha^{-1}, and they were higher by 0.16 t·ha^{-1} and 0.14 t·ha^{-1}, respectively in comparison with treatments without nitrogen fertilization (Table 2). The application of the highest level of nitrogen fertilization caused a decrease in protein yield (significant difference) and digestible protein yield (non significant difference) in comparison with a dose of 90 kg N·ha^{-1}. According to Kruczek [1983], of the nutritive components of maize grain, only the protein content increases with the increase of nitrogen fertilization level and it has a linear character.

With reference to the yield of protein and the yield of digestible protein, it was shown that there was an influence of the cultivar and the nitrogen fertilization level on the values of these features (Fig. 2 and 3). These dependences have been described by quadratic equations, whereby for the hybrid of stay-green type these dependences occurred on a higher level. In case of the cultivar LG 2244 (stay-green type), the maximal yield of protein and the yield of digestible protein (0.98 t·ha^{-1} and 0.87 t·ha^{-1}) were obtained with doses of 115.2 kg N·ha^{-1} and 113.1 kg N·ha^{-1}, while for the hybrid Anjou 258, the maximal yields of protein and digestible protein (0.93 t·ha^{-1} and 0.80 t·ha^{-1}) were obtained for the doses: 97.7 kg N·ha^{-1} and 74.7 kg N·ha^{-1}, respectively.

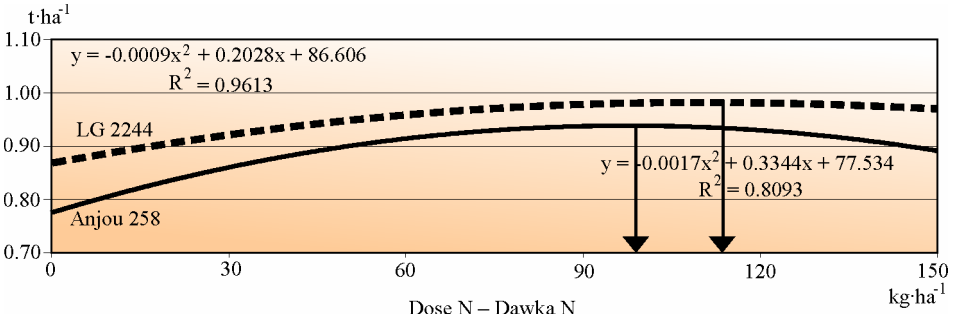

Fig. 2. Protein yield in grain depending on the cultivar and on nitrogen fertilization
Rys. 2. Plon białka w ziarnie w zależności od odmiany i nawożenia azotem

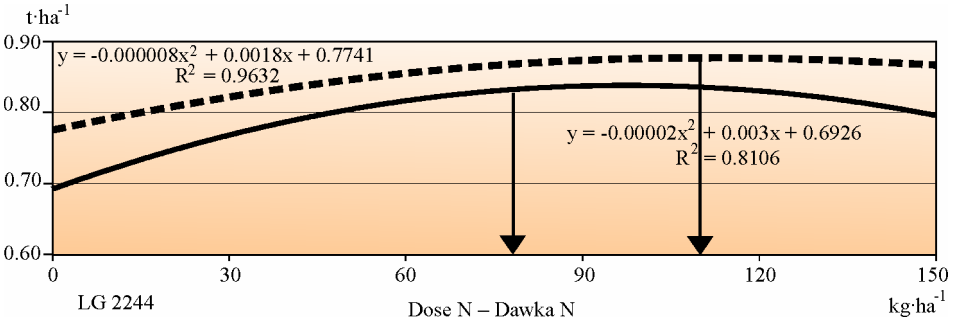

Fig. 3. Digestible protein yield in grain depending on the cultivar and on nitrogen fertilization
Rys. 3. Plon białka strawnego w ziarnie w zależności od odmiany i nawożenia azotem

Protein yield depended also on the interaction of magnesium and nitrogen fertilization (Fig. 3). In case of nitrogen doses without magnesium, no significant effect on the size of this feature was observed. The mean yield of protein for 6 doses of nitrogen amounted to 0.91 t·ha^{-1} (Fig. 4). These dependences were shown for a dose of 15 kg Mg·ha^{-1} (sown by broadcasting) and for a dose of 15 kg Mg·ha^{-1} (in rows). Both curves were described by quadratic equations. In case of the magnesium dose sown in rows, the maximal yield of protein was 0.95 t·ha^{-1} for a nitrogen dose of 99.0 kg N·ha^{-1}, while for the magnesium dose applied by broadcasting, the maximal yield of protein (0.97 t·ha^{-1}) was obtained for a nitrogen dose of 99.7 kg N·ha^{-1}. Magnesium dose of 15 kg Mg·ha^{-1} (by broadcasting) gave an increase in protein yield by 0.18 t·ha^{-1}, as compared with Mg application in rows with a not much higher level of nitrogen fertilization. On the other hand, the application of 15 kg Mg·ha^{-1} (sown in rows) and 15 kg Mg·ha^{-1} (broadcast) caused an increase in protein yield, in comparison with the application of nitrogen without magnesium by 0.37 t·ha^{-1} and 0.55 t·ha^{-1}, respectively.

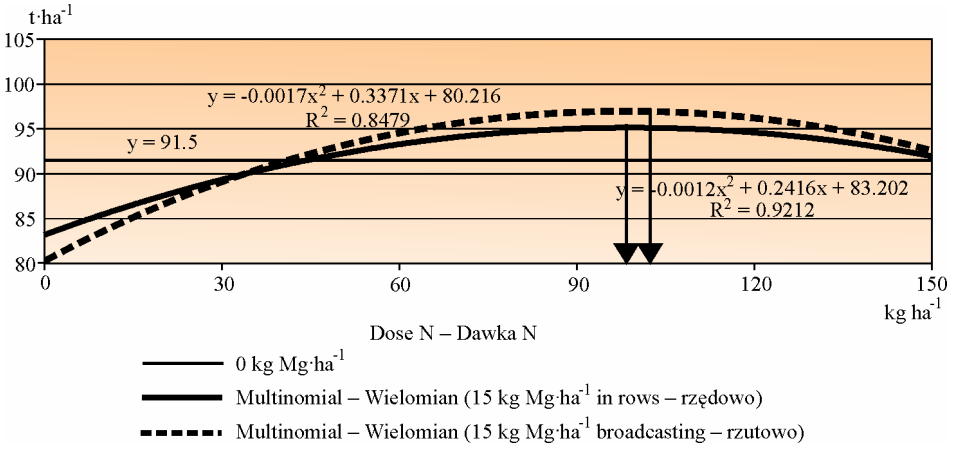

Fig. 4. Protein yield in grain depending on the application method of magnesium and on nitrogen fertilization

Rys. 4. Plon białka w ziarnie w zależności od sposobu wysiewu dawki magnezu i nawożenia azotem

CONCLUSIONS

1. Content of total protein and nitrogen free extract in maize grain depended exclusively on the level of nitrogen fertilization, while the content of ash depended on the cultivar type.

2. The highest value of net energy feature was obtained using for fertilization a dose of 90 kg N·ha^{-1}.

3. The highest yields of protein and digestible protein were obtained for the hybrid of stay-green type, in comparison with Anjou 258, and on the treatments fertilized with a dose of 90 kg N·ha^{-1}.

4. Fertilization of maize with nitrogen and magnesium (in rows, by broadcasting) increased the protein yield in comparison with exclusive fertilization with nitrogen.

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POPRAWA EFEKTYWNOŚCI NAWOŻENIA KUKURYDZY (*Zea mays* L.) AZOTEM POPRZEZ ZASTOSOWANIE MAGNEZU CZ. II. ZAWARTOŚĆ SKŁADNIKÓW POKARMOWYCH W ZIARNIE ORAZ WARTOŚĆ ENERGETYCZNA

Streszczenie. Doświadczenie polowe przeprowadzono w Zakładzie Dydaktyczno-Doświadczalnym w Swadzimiu (52°26' N; 16°45' E) koło Poznania w latach 2004-2007. Doświadczenie prowadzono w układzie „split-plot" z 3 czynnikami w 4 powtórzeniach polowych. Badano 2 odmiany, stosując 6 dawek azotu oraz dawki magnezu (sposób ich aplikacji). Oceniano wpływ tych czynników na wartość energetyczną surowca kukurydzy w uprawie na ziarno. Zawartość białka ogólnego oraz związków bezazotowych wyciągowych w suchej masie ziarna zależała od poziomu nawożenia azotem. W przypadku popiołu wykazano jedynie wpływ odmian na wartość tej cechy, natomiast procentową zawartość włókna surowego oraz tłuszczu surowego nie determinował żaden czynnik doświadczenia. Wyższy plon białka ogólnego – w stosunku do Anjou 258 – stwierdzono

dla mieszańca LG 2244. Rozpatrując wielkość nawożenia azotem, wykazano, że istotnie najwyższy plon białka uzyskano stosując dawkę 90 kg $N \cdot ha^{-1}$, natomiast dalsze zwiększenie dawki azotu powodowało istotne załamanie wielkości tej cechy. Nie stwierdzono wpływu wielkości dawki magnezu oraz sposobu jej aplikacji na plon białka ogólnego. Koncentracja energii netto ziarna nie była zdeterminowana żadnym czynnikiem doświadczenia, natomiast plon energii netto ziarna – wyłącznie wielkością dawki azotu. Plon białka strawnego zależał od typu odmiany i poziomu nawożenia azotem.

Słowa kluczowe: azot, kukurydza, magnez, sposób aplikacji Mg, typy odmian

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