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RESPONSE OF MAIZE HYBRID (*Zea mays* L.), STAY-GREEN TYPE TO FERTILIZATION WITH NITROGEN, SULPHUR, AND MAGNESIUM PART I. YIELDS AND CHEMICAL COMPOSITION

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Abstract. Field experiment was carried out in the Didactic and Experimental Department in Swadzim near Poznań, in years 2004-2005 (52°26' N; 16°45' E). The experiment was established in a „split-plot" design with two factors and four field replications. The primary factor consisted in three nitrogen doses: 0, 60, and 120 kg N·ha^{-1}, while the secondary factor included four doses of kieserite (magnesium sulphate): 0 kg fertilizer·ha^{-1}, 100 kg fertilizer·ha^{-1} (25 kg MgO·ha^{-1} + 20 kg S·ha^{-1}), 200 kg fertilizer·ha^{-1} (50 kg MgO·ha^{-1} + 40 kg S·ha^{-1}), and 300 kg fertilizer·ha^{-1} (75 kg MgO·ha^{-1} + 60 kg S·ha^{-1}). An increase in the nitrogen dose increased grain yield, its moisture, and weight of 1000 grains but it decreased the yield index and the number of production ears. Under the influence of the magnesium sulphate fertilizer (kieserite), maize produced a higher yield of grains while limiting the vegetative biomass. The level of fertilization with nitrogen and kieserite differentiated the nitrogen content in the dry matter of grain and the magnesium content in the dry matter of ears. With an increased nitrogen fertilization, the content of crude fibre in the dry matter of grain increased, while the number of extraction compounds decreased. An increased dose of kieserite decreased the quantity of crude fibre in the dry matter of grain but, at the same time, it increased the amount of N-free extract. The highest yield of net energy, yield of digestible protein, and total protein were obtained for the dose of 120 kg N·ha^{-1}.

Key words: energy of grain and ears yield, grain yield, kieserite, maize, nitrogen, stay-green, yield components

INTRODUCTION

Yield-creating role of fertilization most frequently refers to the application of all-important components, particularly nitrogen [Potarzycki 2008]. However, this is a wrong procedure because, for correct development, maize requires not only nitrogen,

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phosphorus or potassium, also but magnesium and sulphur [Grzebisz and Gaj 2007, Grzebisz 2008b]. Insufficient amount of magnesium in soil causes plants no to utilize properly other elements necessary for regular growth and development [Marska 1994]. In the plant, magnesium performs the function of an activator of the processes responsible for the uptake of mineral components from the soil, while sulphur plays an important role in nitrogen metabolism [Friedrich and Schrader 1978, Schung et al. 1993, Fotyma 2003]. Kieserite (magnesium sulphate – 25% MgO and 20% S) is the fertilizer that contains in its composition both of these nutritive components.

The hypothesis of the undertaken experiment assumed that magnesium and sulphur, whose deficits are found in the majority of Polish soils, can exert an effect on the yield size of high-production plants, including maize and, additionally, they can improve the effectiveness of nitrogen applied in mineral fertilizer. In this connection, studies were undertaken with the purpose of determining the effect of the sizes of nitrogen and kieserite (magnesium sulphate) doses on maize yield, „stay-green" type, grown for grain.

MATERIAL AND METHODS

Field experiment was carried out in the Department of Agronomy, Poznań University of Life Sciences, in the fields of the Experimental and Didactic Farm in Swadzim (52°26' N; 16°45' E), in years 2004-2005. The experiments were conducted in a split-plot design with two experimental factors in four field replications. The primary factor included three doses of nitrogen: 0, 60, and 120 kg $N \cdot ha^{-1}$. The secondary factor included four doses of kieserite (magnesium sulphate): 0 kg fertilizer$\cdot ha^{-1}$, 100 kg fertilizer$\cdot ha^{-1}$ (25 kg $MgO \cdot ha^{-1}$ + 20 kg $S \cdot ha^{-1}$, 200 kg fertilizer$\cdot ha^{-1}$ (50 kg $MgO \cdot ha^{-1}$ + 40 kg $S \cdot ha^{-1}$), and 300 kg fertilizer$\cdot ha^{-1}$ (75 kg $MgO \cdot ha^{-1}$ + 60 kg $S \cdot ha^{-1}$). Fertilization with P and K was carried out before maize sowing in the following doses: 80 kg $P_2O_5 \cdot ha^{-1}$ (35.2 kg $P \cdot ha^{-1}$) in the form of Polifoska 6, and 120 kg $K_2O \cdot ha^{-1}$ (99.6 kg $K \cdot ha^{-1}$) in the form of 60% potassium salt. Nitrogen was applied in the form of urea (46% N). In the experiment, hybrid LG 2244 „stay-green" type FAO 240 was used. Maize sowing was done at the depth of 5-6 cm with a single-seed drill (Monosem), while harvest was carried out using a plot-combine. Analyses of the content of mineral and nutritive components and of the energetic value of grain and ears were carried out basing on the methods contained in the earlier works by the author [Szulc et al. 2008c, Szulc 2009].

Experiments were established on podsolic grey-brown soil of light loamy sand type, shallowly lying on light loam belonging to good rye complex. Magnesium content in the soil was determined using the Schachtschabel method, while potassium and phosphorus by the Egner-Riehm method. Soil abundance in phosphorus in the years of the studies amounted to 55-72 mg $P \cdot kg^{-1}$, potassium 120-171 mg $K \cdot kg^{-1}$, and magnesium 56-95 mg $Mg \cdot kg^{-1}$. The pH values of the soil determined in 1 mol KCl were 5.55-5.87. The courses of temperature and moisture conditions in the period of the studies are presented in a complex way in a climatic diagram elaborated according to the Walter's [1976] method (Fig. 1).

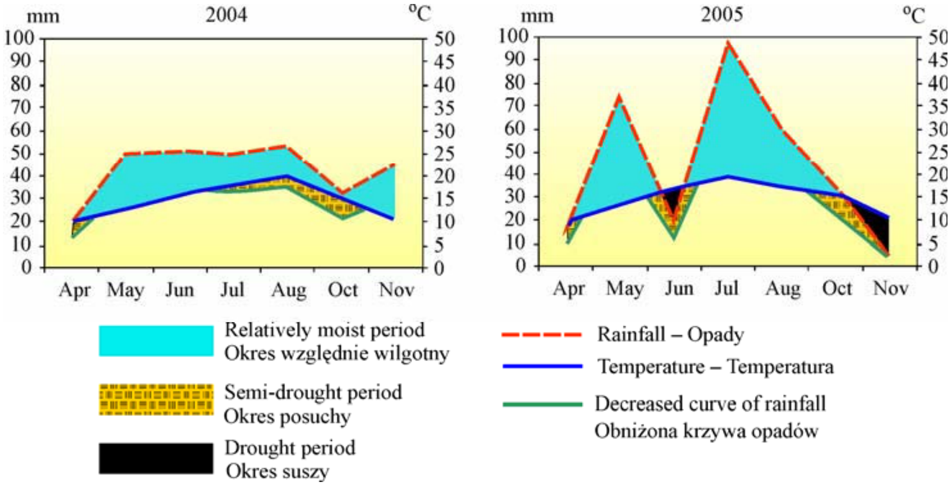

Fig. 1. Weather conditions at the Experimental Agricultural Station in Swadzim from April to November in 2004-2005

Rys. 1. Warunki meteorologiczne w Zakładzie Doświadczalno-Dydaktycznym w Swadzimiu od kwietnia do listopada w latach 2004-2005

Results from one-year studies were subject to the monomial analyses of variance; subsequently, a synthesis of experiments from many years was carried out using the statistical program STATPAKU. The significance of differences was estimated at the level of $\alpha = 0.05$.

RESULTS AND DISCUSSION

Significant effect of nitrogen and kieserite dose sizes, as well as their mutual effect on maize grain yield was found (Table 1, Fig. 2). Grain yield increased in the interval of nitrogen doses from 0 to 120 kg $N \cdot ha^{-1}$ (from 8.06 to 8.52 $t \cdot ha^{-1}$, respectively). Fertilization of maize with kieserite in the range of doses from 0 to 200 kg $fertilizer \cdot ha^{-1}$ (50 kg $MgO \cdot ha^{-1}$ + 40 kg $S \cdot ha^{-1}$) significantly increased in a linear way the size of grain yield. In the case of the highest kieserite doses, i.e. 300 kg $fertilizer \cdot ha^{-1}$ (75 kg $MgO \cdot ha^{-1}$ + 60 kg $S \cdot ha^{-1}$), grain yield increment in relation to the fertilizer dose (200 $kg \cdot ha^{-1}$) was not significant, amounting to 0.03 $t \cdot ha^{-1}$. A slightly different reaction to kieserite dose size was shown in our earlier studies [Szulc et al. 2008b], where the highest grain yield (7.57 $t \cdot ha^{-1}$) was obtained for the kieserite dose of 100 kg $fertilizer \cdot ha^{-1}$ (25 kg $MgO \cdot ha^{-1}$ + 20 kg $S \cdot ha^{-1}$). In turn, the application of 200 kg $kieserite \cdot ha^{-1}$ caused a decrease in grain yield by 0.03 $t \cdot ha^{-1}$. However, one must underscore that the quoted results were obtained for the traditional hybrid and not for the hybrid of the stay-green type.

Table 1. Yield of maize grain, grain moisture, and harvest index
Tabela 1. Plon ziarna kukurydzy, wilgotność ziarna i wskaźnik zbioru

Experimental factor Czynnik doświadczenia		Yield of grain Plon ziarna $t \cdot ha^{-1}$	Moisture of grain Wilgotność ziarna %	Harvest index Wskaźnik zbioru
Nitrogen dose Dawka azotu $kg\ N \cdot ha^{-1}$	0	8.06	25.1	0.49
	60	8.39	25.4	0.48
	120	8.52	25.8	0.47
$LSD_{0.05}$ – $NIR_{0,05}$		0.124	0.28	0.011
Kieserite dose Dawka kizerytu $kg\ N \cdot ha^{-1}$	0	8.10	25.0	0.47
	100	8.28	25.4	0.47
	200	8.44	25.5	0.49
	300	8.47	25.7	0.50
$LSD_{0.05}$ – $NIR_{0,05}$		0.153	0.21	0.010

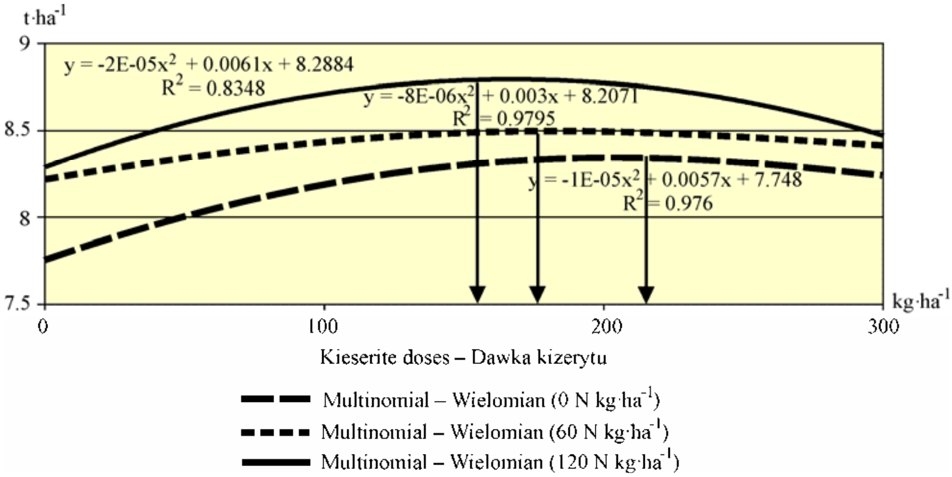

Fig. 2. Maize grain yield depending on the interaction between nitrogen doses and kieserite doses
Rys. 2. Plon ziarna kukurydzy w zależności od współdziałania dawek azotu z dawkami kizerytu

The interaction of nitrogen doses with the doses of kieserite (magnesium sulphate) was described by an equation of the second degree (Fig. 2). For the nitrogen doses of 0 kg N $kg \cdot ha^{-1}$, the maximal grain yield amounting to 8.34 $t \cdot ha^{-1}$ was obtained after the application of 207.6 kg $kieserite \cdot ha^{-1}$ (51.9 kg $MgO \cdot ha^{-1}$+41.5 kg $S \cdot ha^{-1}$). On the other hand, the dose of 60 kg $N \cdot ha^{-1}$ produced the maximal grain yield of 8.45 $t \cdot ha^{-1}$ for the dose of 188.7 kg $kieserite \cdot ha^{-1}$ (47.2 kg $MgO \cdot ha^{-1}$+ 37.7 kg $S \cdot ha^{-1}$). For the dose of 120 kg $N \cdot ha^{-1}$, the highest grain yield (8.75 $t \cdot ha^{-1}$) was obtained with the dose of 151.5 kg $kieserite \cdot ha^{-1}$ (37.9 kg $MgO \cdot ha^{-1}$ + 30.3 kg $S \cdot ha^{-1}$). As reported by Grzebisz and Härdter [2006], the basic task of magnesium and sulphur is the increase in grain yield through better utilization of nitrogen supplied with the fertilizer. Both of these mineral elements permit, by effective balancing of the nitrogen, to increase significantly the utilization of N contained both in the soil and in the fertilizer.

Water content in grain changed in a significant way under the influence of nitrogen and kieserite dose sizes (Table 1). With the increasing doses, water content in grain significantly increased as well (for N doses, it increased from 25.1 to 25.8%, while for kieserite doses, the increase ranged from 25.0 to 25.7%).

In our studies, the harvest index was also calculated as the relation of grain dry matter yield to the yield of dry matter of the whole plants (stover and ears) – Table 1. With nitrogen dose size increase, the value of N decreased. The result obtained in our studies was earlier confirmed by the studies of Kruczek [1997], who reported that the value of harvest index decreased after the application of high nitrogen doses in the range of 120-270 kg $N \cdot ha^{-1}$. Grzebisz and Gaj [2007] also confirmed this relation. According to the latter author, the yield-creating reaction of maize to N doses exceeding 150 kg $N \cdot ha^{-1}$ was not high. A too high dose of nitrogen leads to an excessive production of vegetative matter with a great amount of leaves and weak stems. Plants over-fertilized with nitrogen start flowering later, they mature more slowly (water content in grain is higher) and, in consequence, it leads to a decrease in grain yield [Grzebisz 2008a]. In the case of kieserite doses, the value of harvest index increased with the kieserite dose (Table 2). This testifies that maize under the influence of magnesium and sulphur contained in kieserite created a higher grain yield, limiting at the same time the production of negative yield (biomass).

Table 2. Structure of grain yield
Tabela 2. Struktura plonu ziarna

Experimental factor Czynnik doświadczenia		Number of ears Liczba kolb szt.·m^{-2}	Number of grains in ear Liczba ziaren w kolbie szt.	Weight of 1000 grains Masa 1000 ziaren g
Nitrogen dose	0	7.84	427.0	305.8
Dawka azotu	60	7.71	428.8	318.9
kg $N \cdot ha^{-1}$	120	7.63	421.0	320.4
$LSD_{0.05}$ – $NIR_{0,05}$		0.101	ns – ni	11.49
Kieserite dose	0	7.67	423.6	307.7
Dawka kizerytu	100	7.78	429.5	313.0
kg $N \cdot ha^{-1}$	200	7.68	419.8	317.0
	300	7.76	429.4	322.4
$LSD_{0.05}$ – $NIR_{0,05}$		ns – ni	ns – ni	7.98

ns – ni – non-significant differences – różnice nieistotne

In our studies, no effects of the studied experimental factors were found to be exerted on the number of grains in the ear (Table 2). In turn, the number of production ears in one area unit was determined in a significant way only by nitrogen dose size (Table 2). Increase in the fertilization level with kieserite caused a significant decrease in the number of production ears in one area unit from 7.84 pcs·m^{-2} (0 kg $N \cdot ha^{-1}$) to 7.63 pcs·m^{-2} (120 kg $N \cdot ha^{-1}$). The decrease in the ear number in the area unit together with the increase in the N fertilization level was also shown in our earlier studies [Szulc et al. 2008a]. The number of production ears is very strongly correlated with the quantitative state of plants. Borowiecki and Koter [1983] reported that poor plant germination and inhibition of plant growth in objects with high doses of urea were caused by high concentration of ammonium nitrogen in the soil as a result of urea hydrolysis. This fact can also explain the smaller number of ears per area unit with the increasing doses of urea.

In the case of 1000 grain weight (TGW), a significant effect of nitrogen and kieserite was found to be exerted on this feature (Table 2). With their growth, TGW increased in a linear way (respectively, for the nitrogen doses: from 305.8 g to 320.4 g, and for the kieserite doses: from 307.0 to 322.4 g). In the phase of grain maturing, a close relation between magnesium content in grain and the weight of 1000 grains occurs. Correct nutrition of maize with magnesium is reflected in the growth of grain weight and is revealed in the final yield [Grzebisz and Härdter 2006]. The above presented relation was confirmed in our studies. The increase in the percent content of magnesium in grain caused its yield to increase (Fig. 3).

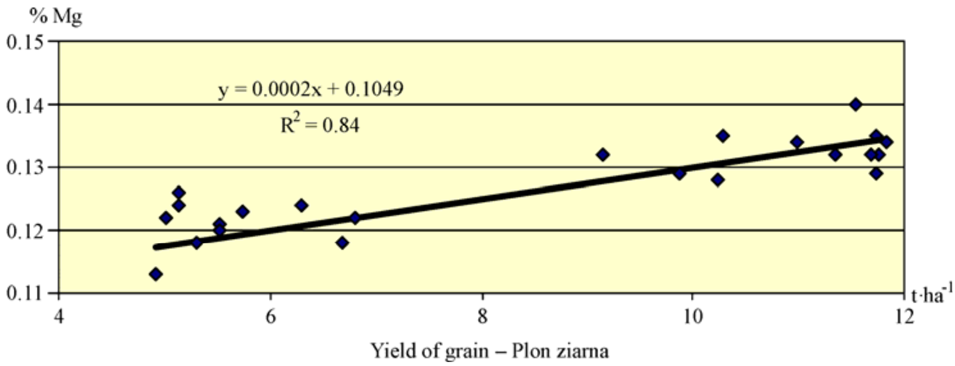

Fig. 3. Relation between grain yield and magnesium content in the d.m. of grain
Rys. 3. Zależność wielkości plonu ziarna od zawartości magnezu w s.m. ziarna

The TGW size in the presented experiment depended on the interaction of N dose size with the dose size of kieserite (Fig. 4). For N dose 0 kg $N \cdot ha^{-1}$, the maximal TGW value of 312.7 g was obtained after the application of 181.5 kg $kieserite \cdot ha^{-1}$ (45.3 kg $MgO \cdot ha^{-1}$ + 36.3 kg $S \cdot ha^{-1}$). On the other hand, the dose of 60 kg $N \cdot ha^{-1}$ gave the maximal TGW value of 320.5 g for the kieserite dose of 195.0 kg $kieserite \cdot ha^{-1}$ (48.7 kg $MgO \cdot ha^{-1}$ + 39.0 kg $S \cdot ha^{-1}$), while for the dose of 120 kg $N \cdot ha^{-1}$, the highest value of this feature (327.1 g) was obtained using 256.2 of $kieserite \cdot ha^{-1}$ (64.0 kg $MgO \cdot ha^{-1}$ + 51.2 kg $S \cdot ha^{-1}$).

Nitrogen content in the dry matter of grain significantly depended on the fertilization level with nitrogen and on the applied dose of kieserite (Table 3). With the increase in nitrogen dose, its content in the dry matter of grain increased from 15.1 $g \cdot kg^{-1}$ (0 kg $N \cdot ha^{-1}$) to 16.8 $g \cdot kg^{-1}$ (120 kg $N \cdot ha^{-1}$). In the case of kieserite, the smallest amount of nitrogen in the dry matter of grain (15.5 $g \cdot kg^{-1}$) was obtained for the dose of 0 kg $fertilizer \cdot ha^{-1}$, while the highest amount (16.6 $g \cdot kg^{-1}$) was shown by the dose of 100 kg $kieserite \cdot ha^{-1}$ (25 kg $MgO \cdot ha^{-1}$ + 20 kg $S \cdot ha^{-1}$). As reported by Grzebisz [2008a], a significant source of nitrogen (protein) in grain is nitrogen accumulated before flowering in the vegetative plant organs. From these resources, about 40-50% is remobilized and secondarily introduced into the organic structures of grains. Hence, it is of crucial importance to ensure that the photosynthetic activity of leaves lasts as long as possible. Such property is possessed by maize hybrids of the „stay-green" type. These hybrids represent phenotypes which show a delayed aging, they have a higher content of water and chlorophyll in their leaf blades in comparison with the traditional maize cultivars [Thomas and Smart 1993].

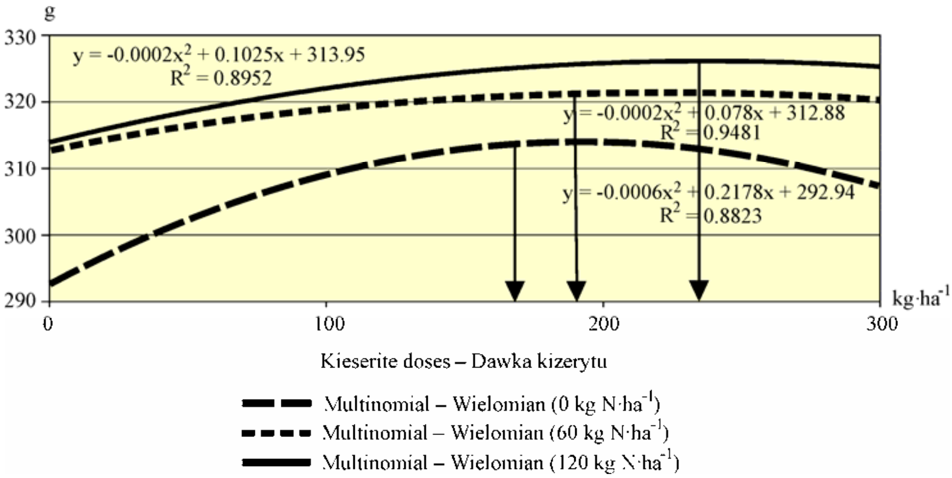

Fig. 4. Weight of 1000 grain (TGW) depending on the interaction between nitrogen doses and kieserite doses
Rys. 4. MTN w zależności od współdziałania dawek azotu z kizerytem

Table 3. Content of mineral components
Tabela 3. Zawartość składników mineralnych

Experimental factor Czynnik doświadczenia		Mineral components, $g \cdot kg^{-1}$ of d.m. Składniki mineralne, $g \cdot kg^{-1}$ s.m.									
		N		P		K		Mg		Ca	
		grain ziarno	ear kolba	grain ziarno	ear kolba	grain ziarno	ear kolba	grain ziarno	ear kolba	grain ziarno	ear kolba
Nitrogen dose Dawka azotu $kg\ N \cdot ha^{-1}$	0	15.1	10.3	2.83	2.80	3.67	2.76	1.26	1.32	0.96	1.29
	60	16.2	11.3	2.95	2.61	3.65	3.01	1.28	1.40	0.97	1.33
	120	16.8	10.9	2.71	2.76	3.55	3.17	1.22	1.51	0.92	0.96
$LSD_{0.05}$ – $NIR_{0,05}$		1.38	ns – ni	ns – ni	ns – ni	ns – ni	ns – ni	ns – ni	0.069	ns – ni	ns – ni
Kieserite dose Dawka kizerytu $kg\ N \cdot ha^{-1}$	0	15.5	11.4	2.82	2.76	3.66	3.51	1.26	1.14	0.92	1.33
	100	16.6	11.0	2.92	2.73	3.64	2.83	1.25	1.37	0.98	1.06
	200	16.0	10.5	2.91	2.64	3.65	3.01	1.27	1.39	0.98	1.26
	300	15.6	10.5	2.66	2.76	3.50	2.57	1.23	1.45	0.92	1.10
$LSD_{0.05}$ – $NIR_{0,05}$		0.54	ns – ni	ns – ni	ns – ni	ns – ni	ns – ni	ns – ni	0.042	ns – ni	ns – ni

ns – ni – non-significant differences – różnice nieistotne

In our own studies, no effect of the experimental factors was found to be exerted on the contents of phosphorus, potassium, magnesium, and calcium in grain dry matter (Table 3). Such effect was only found in the case of magnesium content in the dry matter of ears (Table 3). Increasing fertilization level with nitrogen and kieserite (magnesium sulphate) caused an increase in these macroelements in the dry matter of ears (for nitrogen from 1.32 to 1.51 $g \cdot kg^{-1}$, whilst for kieserite from 1.14 to 1.45 $g \cdot kg^{-1}$) – Table 3.

Content of total protein in the d.m. of grain and the d.m. of ears was significantly determined by the level of nitrogen fertilization (Table 4). The smallest amount of total protein was obtained for the dose of 0 $kg\ N \cdot ha^{-1}$ (93.8 $g \cdot kg^{-1}$ and 88.1 $g \cdot kg^{-1}$, respectively), while the highest amount of total protein was obtained for the dose of 120 kg N·ha^{-1} (105.0 g·kg^{-1} and 99.8 g·kg^{-1}, respectively). Between the doses of 60 kg N·ha^{-1} and 120 kg N·ha^{-1}, no significant difference in the values of this feature was obtained (Table 4). Own studies confirmed the earlier experimental results of Kruczek [2004]. Kruczek fertilized maize with nitrogen doses in the ranges from 25 to 130 kg N·ha^{-1} and obtained an increase in the percent content of protein and a decrease in nitrogen-free extracts in the grain under the influence of the increasing fertilization level. Maize protein, due to low content of lysine and tryptophan is characterized by small biological value but it shows good digestibility [Lipiński 2003].

Doses of nitrogen and kieserite determined in a significant way the content of crude fibre and nitrogen-free extracts in the dry matter of grain (Table 4). With the increase in the nitrogen dose, the content of crude fibre in dry matter increased from 23.6 to 25.3 g·kg^{-1}, while the content of nitrogen-free extracts decreased from 816 to 806 g·kg^{-1} (Table 4). In reference to the kieserite doses, their increase caused a decrease in crude fibre content in the dry matter of grain from 25.0 g·kg^{-1} (0 kg kieserite·ha^{-1}) to 23.6 g·kg^{-1} (300 kg kieserite·ha^{-1}) but the nitrogen-free extracts increased from 807 g·kg^{-1} (0 kg kieserite·ha^{-1}) to 814 g·kg^{-1} (300 kg kieresite·ha^{-1}) – Table 4. In the case of the remaining nutritive components, i.e. ash and crude fat, none of the studied experimental factors differentiated in a significant way their contents in the dry matter of grain and in the d.m. of ears (Table 4). Bruździak [1988] reported that over 80% of fatty compounds accumulate in grain, while the remaining part accumulates in the vegetative organs. In grain, crude fat accumulates mainly in grain germs performing the function of a high energetic reserve substance.

Table 4. Content of nutritional components
Tabela 4. Zawartość składników pokarmowych

Experimental factor Czynnik doświadczenia		Nutritional components, g·kg^{-1} of d.m. – Składniki pokarmowe, g·kg^{-1} s.m									
		total protein białko ogólne		crude fibre włókno surowe		ash popiół		crude fat tłuszcz surowy		N-free extract BNW	
		grain ziarno	ear kolba	grain ziarno	ear kolba	grain ziarno	ear kolba	grain ziarno	ear kolba	grain ziarno	ear kolba
Nitrogen dose Dawka azotu kg N·ha^{-1}	0	93.8	88.1	23.6	64.2	20.5	16.5	45.1	41.7	816	789
	60	101.0	96.4	24.2	61.5	20.6	15.8	43.9	42.4	809	778
	120	105.0	99.8	25.3	62.6	20.7	16.7	42.3	422	806	784
$LSD_{0.05}$ – $NIR_{0,05}$		4.90	10.41	1.17	ns – ni	ns – ni	ns – ni	ns – ni	ns – ni	8.11	ns – ni
Kieserite dose Dawka kizerytu kg N·ha^{-1}	0	103.0	99.3	25.0	65.1	19.8	15.8	44.3	42.7	807	775
	100	99.7	93.1	24.6	61.5	21.2	16.7	43.7	41.6	810	787
	200	100.0	95.7	24.2	61.0	21.0	15.7	43.2	40.8	811	785
	300	97.7	90.9	23.6	63.4	20.4	17.1	43.9	43.2	814	787
$LSD_{0.05}$ – $NIR_{0,05}$		ns – ni	ns – ni	1.17	ns – ni	ns – ni	ns – ni	ns – ni	ns – ni	3.20	ns – ni

ns – ni – non-significant differences – różnice nieistotne

On average, in the period of two years of the studies, none of the studied experimental factors demonstrated in any significant way any net energy concentration in grain or ears (Table 5). Szulc et al. [2008c] also did not show any significant effect of the cultivar type or the nitrogen dose size and magnesium dose size on the value of the discussed feature.

The size of net energy yield of grain and ears was in a significant way differentiated by the size of nitrogen and kieserite doses (Table 5). The lowest value of this feature was found for the dose of 0 kg N·ha^{-1} (68.7 GJ·ha^{-1} and 83.2 GJ·ha^{-1}, respectively), while the highest value was shown by the dose of 120 kg N·ha^{-1} (increment by 3.63 GJ·ha^{-1} and 3.26 GJ·ha^{-1}, respectively) – tab. 5. In the case of kieserite, with the increase in its doses, the net energy yield of grain and ears increased from 68.9 GJ·ha^{-1} and 81.4 GJ·ha^{-1} (0 kg fertilization·ha^{-1}) to 72.1 GJ·ha^{-1} and 88.6 GJ·ha^{-1} (300 kg fertilizer·ha^{-1}; 75 kg MgO·ha^{-1} + 60 kg S·ha^{-1}). Also Machul and Borowiecki [2000] found an effect of nitrogen fertilization level on the size of net energy yield. According to those authors, the highest net energy yields and the highest fodder units were obtained with the nitrogen dose of 90 kg·ha^{-1}.

A two-year period of experimental studies showed an effect of the size of the nitrogen dose on the yield of the digestible protein yield in grain and on the total protein yield in grain (Table 5). The smallest amounts of the above mentioned proteins were obtained for the dose of 0 kg N·ha^{-1} (0.48 t·ha^{-1} and 0.63 t·ha^{-1}, respectively), while the highest amount was shown by the dose of 120 kg N·ha^{-1} (0.57 t·ha^{-1} and 0.74 t·ha^{-1}, respectively) – Table 5. In reference to the total protein yield in ears, an effect of the nitrogen dose size on the value of the discussed feature was shown (Table 5). Under the influence of increasing nitrogen fertilization, the total protein yield increased in ears from 0.75 t·ha^{-1} in the control object to 0.85 t·ha^{-1} with the highest dose of nitrogen. In the opinion of Kruczek [1983], among the nutritive components of maize grain, only protein content increases with the increase in the nitrogen fertilization level and it has a linear character.

Table 5. Net energy concentration, net energy yield, total protein yield, and digestible protein yield
Tabela 5. Koncentracja energii netto, plon energii netto, plon białka ogólnego i plon białka strawnego

Experimental factor Czynnik doświadczenia		Net energy concentration Koncentracja energii netto MJ·kg^{-1} d.m. – s.m.		Net energy yield Plon energii netto GJ·ha^{-1}		Digestible protein yield Plon białka strawnego t·ha^{-1}		Total protein yield Plon białka ogólnego t·ha^{-1}	
		grain ziarno	ear kolba	grain ziarno	ear kolba	grain ziarno	ear kolba	grain ziarno	ear kolba
Nitrogen dose Dawka azotu kg N·ha^{-1}	0	10.0	9.82	68.7	83.2	0.48	0.57	0.63	0.75
	60	10.0	9.80	71.3	84.7	0.54	0.65	0.71	0.86
	120	9.99	9.83	72.3	86.5	0.57	0.65	0.74	0.85
$LSD_{0.05}$ – $NIR_{0,05}$		ns – ni	ns – ni	0.83	1.12	0.054	ns – ni	0.050	0.031
Kieserite dose Dawka kizerytu kg N·ha^{-1}	0	10.0	9.78	68.9	81.4	0.54	0.64	0.70	0.83
	100	10.0	9.83	70.4	82.3	0.54	0.64	0.70	0.84
	200	10.0	9.81	71.8	86.9	0.53	0.60	0.69	0.79
	300	10.0	9.83	72.1	88.6	0.52	0.62	0.69	0.81
$LSD_{0.05}$ – $NIR_{0,05}$		ns – ni	ns – ni	0.94	1.12	ns – ni	ns – ni	ns – ni	ns – ni

ns – ni – non-significant differences – różnice nieistotne

SUMMARY

Increase in the nitrogen dose caused an increase in the grain yield and grain moisture but decreased the harvest index. Under the influence of increasing doses of magnesium and sulphur (kieserite) fertilizer, maize produced a higher grain yield while limiting the production of vegetative biomass. Increased level of N fertilization in the form of urea limited the number of production ears. Under the increasing level of fertilization with urea and sulphur and magnesium fertilizer (kieserite), maize produced bigger ears (TGW). Fertilization of maize with nitrogen and kieserite (magnesium sulphate) caused grain yield increment by 0.28 $t \cdot ha^{-1}$ (0 kg $N \cdot ha^{-1}$), about 0.06 $t \cdot ha^{-1}$ (60 kg $N \cdot ha^{-1}$) and by 0.23 $t \cdot ha^{-1}$ (120 kg $N \cdot ha^{-1}$), in comparison with objects without nitrogen fertilization. Increase in the doses of nitrogen and kieserite increased the nitrogen content in the dry matter of grain, while the increase in the magnesium doses increased magnesium content in the ears. The highest content of total protein in the dry matter of ears was obtained with the dose of 120 kg $N \cdot ha^{-1}$. With the increase in nitrogen fertilization, the content of crude fibre in the d.m. of grain increased, while the amount of nitrogen-free extracts decreased. Increase in the kieserite dose caused a decrease in the amount of crude fibre in the dry matter of grain but increased the amount of nitrogen-free extracts. Fertilization level with nitrogen and kieserite did not differentiate the net energy concentration of grains and ears. Net energy yield of grain and ears increased with the level of nitrogen and kieserite dose levels. The highest yield of the digestible protein of grain, grain total protein yield, and ear total protein yield were obtained with the dose of 120 kg $N \cdot ha^{-1}$.

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REAKCJA MIESZAŃCA KUKURYDZY (*Zea mays* L.) TYPU STAY-GREEN NA NAWOŻENIE AZOTEM, SIARKĄ I MAGNEZEM CZ. I. PLONY I SKŁAD CHEMICZNY

Streszczenie. Doświadczenie polowe przeprowadzono w Zakładzie Doświadczalno--Dydaktycznym w Swadzimiu (52°26’ N; 16°45’ E), należącym do Katedry Agronomii

UP w Poznaniu, w latach 2004-2005. Prowadzono je w układzie „split-plot" z 2 czynnikami w 4 powtórzeniach polowych. Czynnikiem I rzędu były trzy dawki azotu: 0, 60 i 120 kg $N \cdot ha^{-1}$, natomiast czynnikiem II rzędu cztery dawki kizerytu (siarczanu magnezu): 0 kg $nawozu \cdot ha^{-1}$, 100 kg $nawozu \cdot ha^{-1}$ (25 kg $MgO \cdot ha^{-1}$ + 20 kg $S \cdot ha^{-1}$), 200 kg $nawozu \cdot ha^{-1}$ (50 kg $MgO \cdot ha^{-1}$ + 40 kg $S \cdot ha^{-1}$) i 300 kg $nawozu \cdot ha^{-1}$ (75 kg $MgO \cdot ha^{-1}$ + 60 kg $S \cdot ha^{-1}$). Wykazano, że wzrost dawki azotu powodował zwiększenie plonu ziarna, jego wilgotności oraz MTN, natomiast zmniejszenie wskaźnika zbioru i liczby kolb produkcyjnych. Pod wpływem nawozu magnezowo-siarkowego (kizerytu) kukurydza wytwarzała większy plon ziarna, ograniczając jednocześnie produkcję biomasy wegetatywnej. Poziom nawożenia azotem i kizerytem różnicował zawartość azotu w s.m. ziarna i magnezu w s.m. kolb. Wraz ze wzrostem dawki nawożenia azotem zwiększała się zawartość włókna surowego w s.m. ziarna, natomiast zmniejszała się ilość związków bezazotowych wyciągowych. Wzrost dawki kizerytu powodował zmniejszenie ilości włókna surowego w s.m. ziarna, natomiast zwiększenie zawartości związków bezazotowych wyciągowych. Największy plon energii netto, plon białka strawnego i plon białka ogólnego uzyskano po zastosowaniu dawki 120 kg $N \cdot ha^{-1}$.

Słowa kluczowe: azot, energia plonu ziarna i kolb, kizeryt, komponenty plonowania, kukurydza, plon ziarna, stay-green

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