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REACTION OF TWO MAIZE CULTIVARS EXPRESSED BY DRY MATTER YIELDS DEPENDING ON NITROGEN FERTILIZATION LEVEL AND ON MAGNESIUM APPLICATION METHOD

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Abstract. Field experiments were carried out at the Didactic and Experimental Farm in Swadzim 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 (Anjou 258 and LG 2244 – stay-green type), 6 doses of nitrogen (0 kg N ha^{-1}, 30 kg N h^{-1}, 60 kg N ha^{-1}, 90 kg N h^{-1}, 120 kg N h^{-1}, 150 kg N ha^{-1}), and one dose of magnesium and method of Mg fertilizer application (0 kg MgO ha^{-1}, 25 kg MgO ha^{-1} – in rows and 25 kg MgO ha^{-1} – broadcasting). The effect of experimental factors on the yield of maize plant dry matter and its content in the phase of 5-6 leaves and during harvest were analysed. A better dynamics of dry matter accumulation in the initial developmental phase was shown by the hybrid LG 2244 (stay-green type) as compared with Anjou 258 cultivar. During harvest, this relation was inverted. The dose of nitrogen modified the yields of maize dry matter in the whole period of maize growth. The applied magnesium fertilization increased the yield of dry matter of straw, cobs and of whole plants. The application of magnesium by broadcasting proved to be a more effective method, as compared with row application.

Keywords: cultivar types, nitrogen, magnesium, fertilizer application method

INTRODUCTION

Among fertilization problems, the most difficult one is the problem of proper method of nitrogen application, where two aspects must be taken into consideration. The first one is the economic aspect deciding about the profitability of the applied fertilization. The other aspect concerns the ecological problem. Because of high mobility of nitrogen, one must take into consideration that it may exert a harmful effect on the natural environment (Grzebisz 2002, Kruczek 1997). Due to the amount and quality of the produced biomass, maize belongs to plants with high nutritive needs (Fotyma 1994, Kruczek 2000). High fertilization level which is required because of the abovementioned reasons qualifies maize among intensive plants. In order to realize the yielding potential of maize, i.e. to achieve the maximal yield of dry matter in given environmental conditions, maize requires complete coverage of all its necessary nutritive components throughout the whole vegetation period. Nitrogen is obviously a component distinctly limiting maize yield (Grzebisz 2002), because its recently increasing prices make maize cultivation unprofitable. The only way which may improve the profitability can be the decrease of nitrogen fertilization cost, or improvement of nitrogen effectiveness which can be achieved in conditions of fertilization optimisation by using nitrogen with other components (Grzebisz 1999). Nitrogen use depends to a high degree on balancing the N dose with phosphorus and potassium and on the availability of a number of other elements, including magnesium (Seidler and Mamzer 1994, Wyszkowski 2000, Wyszkowski 2001).

In reference to the above considerations, studies were undertaken in order to find a method of magnesium application which would permit to reduce the amount of nitrogen fertilization applied to the soil for 2 maize cultivars.

MATERIAL AND METHODS

Field studies were carried out at the Didactic and Experimental Farm in Swadzim near Poznań in the years 2004-2007. Results of studies carried out in 2006 were disqualified because of prevailing drought in the period of maize growth and development. The experiment was carried out in „split-plot" design, with 3 factors in 4 field replications. Two cultivars were studied: Anjou 258 and LG 2244 (stay-green type), six nitrogen doses were used: 0 kg N ha^{-1}, 30 kg N ha^{-1}, 60 kg N ha^{-1}, 90 kg N ha^{-1}, 120 kg N ha^{-1}, 150 kg N ha^{-1} and doses of magnesium: 0 kg MgO ha^{-1}, 25 kg MgO ha^{-1} (in rows) and 25 kg MgO ha^{-1} (broadcasting), in the form of kieserite. Fertilization with P and K was performed before the sowing of maize, in doses of 80 kg P_2O_5 ha^{-1} (35.2 kg P ha^{-1}) in the form of Polifoska 6, and 120 kg K_2O ha^{-1} (99.6 kg K ha^{-1}) in the form of 60% potassium salt.

For maize sowing, a Monosem single seed drill was used, equipped with a fertilizer applicator for magnesium distribution together with seed sowing. Fertilizer coulters were set in relation to seed coulters in such a way that fertilizer was placed in the soil 5 cm aside to the seed and 5 cm below the seed. Seeds were sown 5-6 cm deep. In the phase of 5-6 leaves, from each plot, from 2 middle rows, plant samples were taken for analyses, and then roots were separated from the aboveground parts. After drying, the content of dry matter and dry matter of a single plant were determined. During maize harvest, the weight of the whole plants was measured, and then the weight of cobs alone, the total yield of dry matter and the yield structure were defined. The percentage of maize dry matter in the aboveground parts was calculated as well.

Results of studies were subjected to one-variable analysis of variance, followed by synthesis of multiple experiments. Significance of differences was estimated at the level of $\alpha = 0.05$.

The experiment was carried out on a grey-brown podzolic soil of coarse sandy soil type, shallowly overlying light loam and belonging to good rye complex. Abundance of nutrients in the soil and its acidity are shown in Table l.

Table 1. Soil conditions at Swadzim

Specification	Years		
	2004	2005	2007
$N\text{-}NH_4$ (mg 100 g^{-1} dry mass of soil)	0.13	0.12	0.14
$N\text{-}NO_3$ (mg 100 g^{-1} dry mass of soil)	0.45	0.31	0.32
P (mg P_2O_5 100 g^{-1} of soil)	12.5	16.4	19.0
P (mg P 100 g^{-1} of soil)	5.5	7.2	8.3
K (mg K_2O 100 g^{-1} of soil)	14.6	20.7	20.5
K (mg K 100 g^{-1} of soil)	12.1	17.2	17.1
Mg (mg Mg 100 g^{-1} of soil)	9.5	5.6	7.3
pH (in 1n KCl)	5.87	5.55	6.22

Thermic and moisture conditions during vegetation in the years of studies were favourable for the growth and development of maize (Tab. 2). Rainfall sum in the months of April-September amounted to 301.0 mm in the year 2004, 305.4 mm in 2005, and 332.9 mm in 2007. Hydrothermal coefficients indicating in a complex way both the air temperature and atmospheric precipitations permitted to state that in the period of studies, both the sum of rainfalls and their distribution were favourable for the growth and development of maize. Insignificant deficit of moisture was found in the soil during maize sowing (April 2004, April 2005 and April 2007), as well as in June 2005.

Table 2. Weather conditions at Swadzim

Years	IV	V	VI	VII	VIII	IX	X	IV-X
Temperature in ^oC								
2004	9.7	12.9	16.1	18.2	20.1	14.2	10.4	14.5
2005	9.4	13.3	16.5	19.9	17.3	16.0	10.5	14.7
2007	10.8	15.2	19.3	18.9	19.2	13.7	8.5	15.1
Rainfall in mm								
2004	19.4	49.8	51.3	49.4	53.6	32.3	45.2	301.0
2005	14.5	74.3	19.1	97.4	60.7	34.4	5.0	305.4
2007	9.3	77.0	59.6	87.0	48.1	33.4	18.5	332.9
Hydrothermal coefficient of protection in water according to Sielianinov[1)]								
2004	0.66	1.24	1.06	0.87	0.86	0.76	1.40	0.97
2005	0.49	1.80	0.48	1.57	1.13	0.71	0.15	0.89
2007	0.28	1.63	1.02	1.48	0.81	0.81	0.70	0.96

1. according to Molga (1986),
Interpretation of hydrothermal coefficient,
0.00-0.50 – drought,
0.51-1.00 – half-drought (insufficient moisture for majority of plants),
1.01-2.00) – relative moisture (sufficient moisture for majority of plants),
> 2.01 – large moisture (excessive moisture for majority of plants).

RESULTS AND DISCUSSION

In the phase of 5-6 leaves, a statistically greater dry matter weight of a single plant, yield of dry matter from area unit and dry matter content were found for the hybrid LG 2244 (stay-green type) in relation to the Anjou 258 cultivar (Tab. 3). The differences were 6.6%, 8.3% and 5.1%, respectively. The lowest dry matter weight of a single plant, dry matter yield and dry matter content in the studied development phase were obtained for the dose of 0 kg N ha^{-1} (1.67 g, 126.47 kg ha^{-1} 12.37%, respectively). On the other hand, significantly the highest respective values were obtained for the dose of 120 kg N ha^{-1} (2.09 g, 155.44 kg ha^{-1}, 12.84%, respecively). The application of the dose of 150 kg N ha^{-1} caused a significant break-down of the values of these features. Slightly different results were obtained by Kruczek (2004). That author, who applied maize fertilization in the dose range of 25-130 kg N ha^{-1}, did not obtain any significant effect of nitrogen fertilization on the rate of dry matter accumulation in the phase of 4-5 leaves, as expressed by the dry matter of a single plant and by the plant dry matter yield. Earlier pot experiments of the present authors (Szulc *et al*. 2007) confirm the absence of any effect of maize fertilization with nitrogen on dry matter of a single plant in the phases of 3-4 and 4-5 leaves.

Table 3. Dry mass of aboveground parts of 1 plant, yields and content of dry mass of maize in phase of 5-6 leaves (2004-2007)

Specification		Dry matter		
		1 plant	yield	content of dry matter
		g	kg ha^{-1}	%
Variety	Anjou 258	1.84	136.35	12.22
	LG 2244	1.97	148.68	12.88
	LSD $_{0,05}$	0.130	11.540	0.361
Dose N in kg ha^{-1}	0	1.67	126.47	12.37
	30	1.88	141.06	12.44
	60	1.93	144.89	12.50
	90	1.96	146.91	12.61
	120	2.09	155.44	12.84
	150	1.92	140.33	12.54
	LSD $_{0.05}$	0.106	7.855	0.262
Dose MgO in kg ha^{-1}	0	1.94	145.24	12.51
	25 in rows	1.90	141.02	12.58
	25 broadcasting	1.89	141.29	12.57
	LSD $_{0.05}$	n.s.	n.s.	n.s.

n.s. – non-significant differences.

Magnesium is a macroelement which, in comparison with nitrogen, phosphorus and potassium, acts positively, although in a lesser degree on maize yielding (Mercik and Stępień 1993). The requirement of this plant for magnesium in the initial phases of growth and development is small. This fact explains the absence of any effect exerted by the magnesium dose and by the method of its application on the rate of dry matter accumulation by maize in the phase of 5-6 leaves. According to Mercik *et al*. (1997), the action of magnesium fertilizers on the yielding and on the quality features of plants depends on magnesium content in the soil, and the action is the greater the smaller the amount of this component in the substrate. In our own studies, the content of magnesium in the soil in the years of studies ranged from a medium value to a high one (Tab. 1), causing that there was no maize reaction to the current fertilization with magnesium.

In the phase of 5-6 leaves it was found that the cultivar type and the nitrogen dose size exerted an effect on the accumulation of dry matter by maize (Figs. 1 and 2).

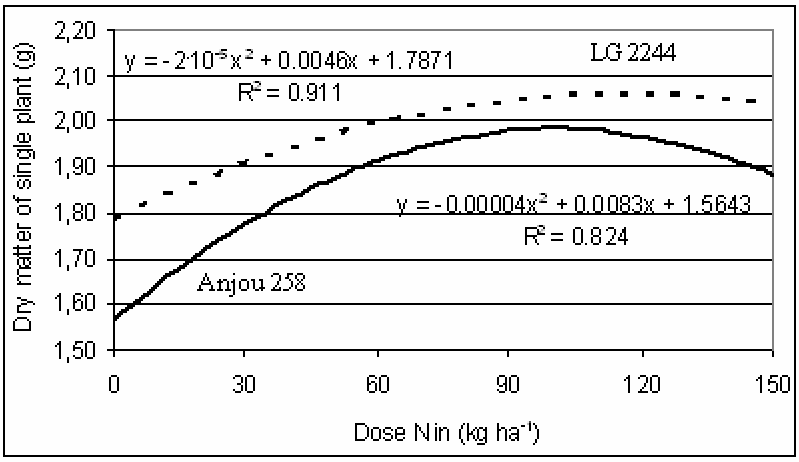

Fig. 1. Dry matter of a single plant in the phase of 5-6 leaves depending on cultivar type and dose of nitrogen fertilization (2004-2007)

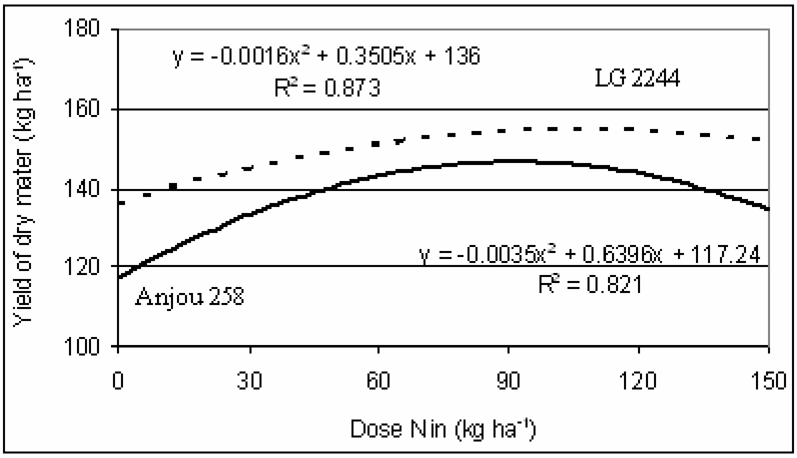

Fig. 2. Yield of dry matter in the phase of 5-6 leaves depending on cultivar type and nitrogen fertilization dose (2004-2007)

These dependences have been described by 2° equations, whereby for the hybrid LG 2244 (stay-green type), this relation took place on a higher level in comparison with Anjou 258 cultivar. In the case of Anjou 258 cv., the maximal dry matter weight of a single plant (1.99 g) and yield of dry matter (146.5 kg ha^{-1}) were obtained for nitrogen doses of 103.7 kg N ha^{-1} and 91.4 kg N ha^{-1}, respectively. On the other hand, the obtained results for the hybrid LG 2244 (stay-green type) were: maximal yield of a single plant dry matter (2.05 g) and the yield of dry matter (154.6 kg ha^{-1}) for nitrogen doses of 115.0 kg N ha^{-1} and 109.5 kg N ha^{-1}, respectively.

The yield of dry matter of straw depended on all 3 experimental factors (Tab. 4). A significantly greater straw dry matter yield was found in the hybrid Anjou 258, as compared with LG 2244 (stay-green type). The difference was 11.43 dt ha^{-1}. Statistically the lowest yield of straw dry matter was obtained for the dose of 0 kg N ha^{-1} (72.57 dt ha^{-1}). The application of nitrogen doses in the range of 30-120 kg N ha^{-1} caused a linear but insignificant increase of the studied feature value. On the other hand, the application of the highest nitrogen dose (150 kg N ha^{-1}) gave an insignificant break-down in the dry matter yield size of maize straw.

Table 4. Yields and content of dry mass of maize (2004-2007)

Specification		Dry mass					
		straw		cob		whole plants	
		dt ha^{-1}	%	dt ha^{-1}	%	dt ha^{-1}	%
Variety	Anjou 258	83.83	39.82	112.37	71.41	196.21	62.28
	LG 2244	72.40	38.04	113.84	73.74	186.24	63.82
	LSD $_{0,05}$	2.201	1.046	r.n.	1.091	8.719	0.853
Dose N in kg ha^{-1}	0	72.57	38.27	107.77	71.85	180.35	62.31
	30	77.94	38.31	110.63	72.50	188.57	63.34
	60	78.05	39.17	111.78	71.82	189.83	62.91
	90	79.42	38.74	113.45	71.76	192.88	62.91
	120	81.97	39.59	118.23	72.48	200.21	63.55
	150	78.75	39.51	116.75	72.03	195.50	63.16
	LSD $_{0.05}$	5.969	r.n.	6.910	r.n.	11.009	r.n.
Dose MgO in kg ha^{-1}	0	77.47	39.28	110.52	71.45	187.99	63.05
	25 in rows	76.80	38.42	115.21	72.71	192.02	63.47
	25 broad-casting	80.07	39.97	113.58	72.06	193.66	62.57
	LSD $_{0.05}$	2.621	n.s.	3.841	n.s.	5.018	n.s.

n.s. – non-significant differences.

The results obtained in our own studies confirms the results obtained by Kruczek (2004). According to that author, increased level of nitrogen fertilization, ranging from 25 to 90 kg N ha^{-1}, caused an increase of straw dry matter, while further increase of the N dose to 130 kg N ha^{-1} did not bring any further increase of the studied feature. A significantly higher yield of dry matter (80.07 dt ha^{-1}) was obtained as a result of application of 25 kg MgO ha^{-1} (broadcasting) in comparison with 0 kg MgO ha^{-1} and 25 kg MgO ha^{-1} (in rows) (Tab. 4). The dry matter content in straw depended exclusively on the cultivar. Statistically higher dry matter content in straw, by 1.78%, was found in the hybrid Anjou 258 in comparison with LG 2244 (stay-green type).

The yield of straw dry matter depended on the interaction between the cultivar type and the dose of nitrogen fertilization (Fig. 3). These dependences have been described by 2° equation. A more intensive accumulation of maize dry matter (before harvest) was shown by the hybrid Anjou 258, while LG 2244 (stay-green type) reached a lower level. In the case of LG 2244 (stay-green type), the maximal yield of dry matter (74.5 dt ha^{-1}) was obtained with the dose of 91.6 kg N ha^{-1}, while for Anjou 258, the maximal yield of dry matter of straw (87.2 dt ha^{-1}) was reached with the dose of 128.6 kg N ha^{-1} .

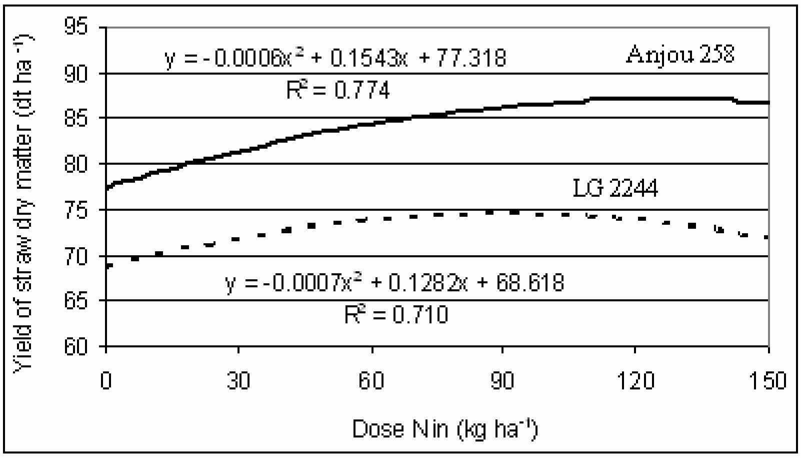

Fig. 3. Yield of straw dry matter depending on cultivar type and nitrogen fertilization dose (2004-2007)

The yield of cob dry matter was modified in a significant way by the N dose size and by the dose of magnesium (Tab. 4). The lowest yield of cob dry matter was obtained with the dose of 0 kg N ha^{-1} (107.77 dt ha^{-1}), while the highest yield was reached with the dose of 120 kg N.ha^{-1} (118.23 dt ha^{-1}). Analysis of magnesium fertilization doses has shown that the lowest yield of cob dry matter was obtained with the dose of 0 kg MgO ha^{-1} (110.52 dt ha^{-1}), while the highest yield was reached with the dose of 25 kg MgO ha^{-1} (in rows) which gave 115.21 dt ha^{-1}. No significant differences were found between the magnesium sowing methods (Tab. 4). The obtained results are confirmed also by other authors (Seidler and Mamzer 1994), according to whom magnesium fertilization distinctly increased both the dry matter and the number of cobs, but the increase was not directly proportional to the applied dose of magnesium fertilization. Fazekas *et al*. (1992) also confirmed the beneficial effect of maize fertilization with magnesium on increase of cob yield. The content of dry matter in the cobs depended exclusively on the plant cultivar. Statistically higher content of dry matter in cobs, by 2.33%, was found in the hybrid LG 2244 (stay-green type) as compared with Anjou 258.

Dry matter yield of whole maize plants depended on all three experimental factors (Tab. 4). For the hybrid Anjou 258, a higher yield of whole plant dry matter, by 5.1%, was obtained in comparison with LG 2244 (stay-green type). The lowest dry matter yield of the whole plant was shown by the dose of 0 kg N ha^{-1} (180.35 dt ha^{-1}), while the highest yield was given by the dose of 120 kg N ha^{-1} (200.21 dt ha^{-1}). Results obtained in our own studies are convergent with the results shown by Kruczek (2004). According to that author, increased fertilization level ranging from 25 to 130 kg N ha^{-1} caused a linear increase of dry matter yield of the whole plants. The lowest yield of whole plants dry matter was obtained with the dose of 0 kg MgO ha^{-1}, while the highest yield was given by the dose of 25 kg MgO ha^{-1} (in rows). Between the methods of magnesium application, no significant differences were found (Tab. 4). The dry matter content of the whole plants depended exclusively on the cultivar factor. Statistically a greater content of dry matter in cobs, by 1.54%, was shown by the hybrid LG 2244 (stay-green type) as compared with Anjou 258.

In the case of dry matter yield of whole plants, there was also an interaction between the cultivar type and the fertilization dose of nitrogen (Fig. 4). These dependences have been described by 2° equation. Anjou 258 was a better cultivar as compared with LG 2244 (stay-green type), because it obtained a higher yield of dry matter for the whole plants (202.9 dt ha^{-1}) with a nitrogen dose lower by 12.4 kg N ha^{-1} in comparison with LG 2244 (stay-green type) which gave 191.1 dtha^{-1}.

An interaction was also shown between fertilization with nitrogen and magnesium on the yield of straw dry matter (Fig. 5). In the case of nitrogen doses without Mg, no significant effect on straw dry matter yield was found. The mean yield of straw dry matter for 6 doses of nitrogen was 77.4 dt ha^{-1}. However, dependences were found for the dose of 25 kg MgO ha^{-1} (broadcast) and for the dose of 25 kg MgO ha^{-1} (in rows). Both curves have been described by 2° equations. When the dose of 25 kg MgO ha^{-1} was hand-broadcast, the yield of straw dry matter increased by 3.1 dt ha^{-1} as compared with the row sowing application of magnesium accompanied by nitrogen dose lower by 9.6 kg N ha^{-1}.

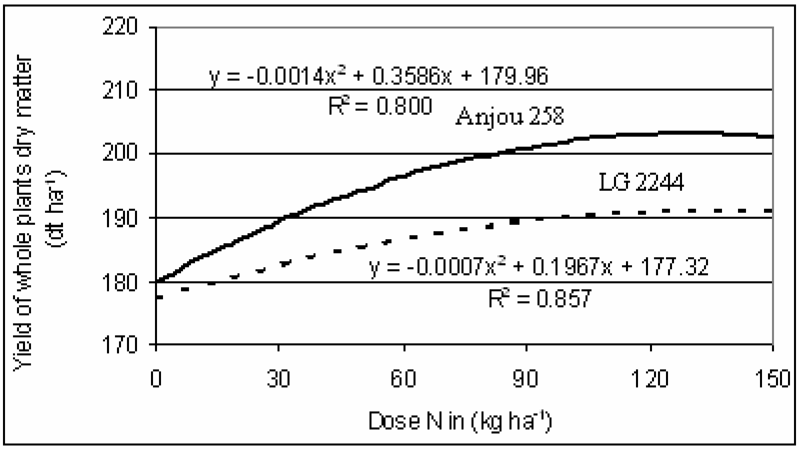

Fig. 4. Yield of whole plants dry matter depending on cultivar type and nitrogen fertilization dose (2004-2007)

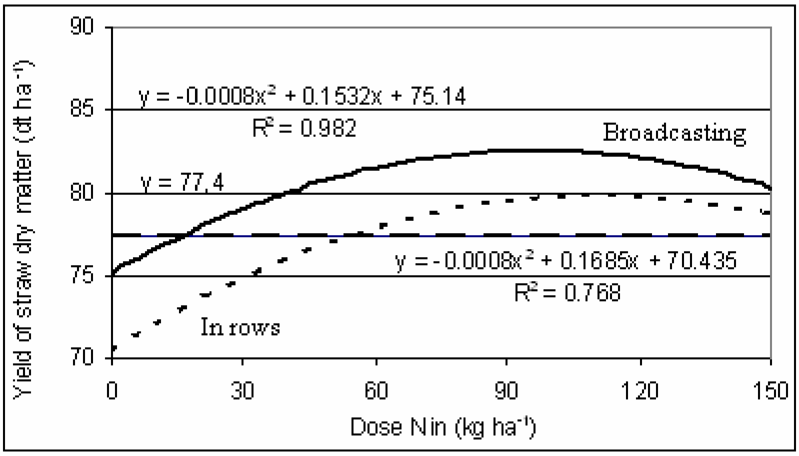

Fig. 5. Yield of straw dry matter depending on application method of magnesium dose and nitrogen fertilization (2004-2007)

The yield of whole plants dry matter depended on the cooperative application of magnesium and nitrogen (Fig. 6). In the case of nitrogen doses without Mg, no significant effect on the yield size of whole plants was found. The mean yield of whole plants dry matter for 6 doses of nitrogen was 188.0 dt ha^{-1}. These dependences were shown for the dose of 25 kg MgO ha^{-1} (broadcast) and for the dose of 25 kg MgO ha^{-1} (in rows). Both curves have been described by 2° equations. In the case of magnesium dose sown in rows, the maximal yield of dry matter for whole plants (200.5 dt ha^{-1}) was obtained using at the same time a nitrogen dose of 118.8 kg N ha^{-1}. On the other hand, when the magnesium dose was applied by hand broadcasting the maximal yield of whole plants (198.9 dt ha^{-1}) was obtained at the nitrogen dose of 112.4 kg N ha^{-1}. Therefore, in the case of dry matter yield of whole plants the difference in the size of the obtained yields between the two methods of magnesium application was definitely smaller, amounting to 0.8%.

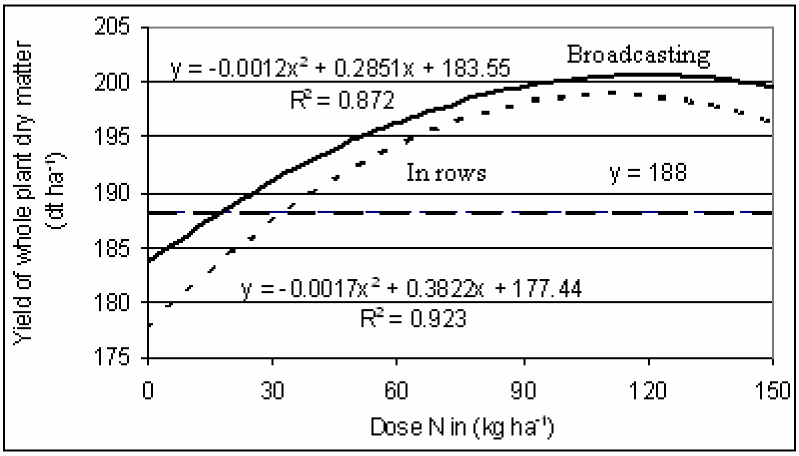

Fig. 6. Yield of whole plants dry matter depending on application method of magnesium dose and nitrogen fertilization (2004-2007)

CONCLUSIONS

1. Cultivar LG 2244 (stay-green type) showed a better initial vigour expressed by the dry matter of a single plant, by the yield of dry matter and by the content of dry matter in the phase of 5-6 leaves in comparison with the hybrid Anjou 258. In the period of maize harvest, the effect of the cultivars on the mentioned features was inverted.

2. Dry matter of a single plant, the yield of dry matter in the phase of 5-6 leaves and the yield of dry matter of straw, of cobs and of whole plants increased in the range of N fertilization doses from 0 kg N ha^{-1} to 120 kg N ha^{-1}. The application of the highest nitrogen dose of 150 kg N ha^{-1} caused a decrease in the values of the studied features.

3. In the phase of 5-6 leaves, no effect was found of the used magnesium dose and of the method of Mg application on the rate of dry matter accumulation by maize.

4. Application of the dose of 25 kg MgO ha^{-1} (broadcast) caused a significant increase of the yield of dry matter of straw, cobs and of whole plants in comparison with plots without magnesium fertilization. In the case of straw dry matter yield, a significantly better method of magnesium application was the hand broadcasting in comparison with the method of sowing in rows. The magnesium application method did not exert any effect on the yield of dry matter of cobs and on the dry matter of whole plants.

5. With the application of the dose of 25 kg MgO ha^{-1} by hand broadcasting, a yield increase of straw dry matter by 3.1 dt ha^{-1} was obtained in comparison with the row sowing (25 kg MgO ha^{-1}) of magnesium and a simultaneous application of nitrogen dose lower by 9.6 kg N ha^{-1}. In the case of dry matter yield of whole plants, the difference in the size of the obtained yields between the two methods of magnesium application was lower by 0.8%.

6. In maize fertilization with N + Mg (broadcast), a dry matter yield increase of straw by 5.1 dt ha^{-1} was obtained, on the other hand, in the application of N + Mg (by in rows), a yield increase of whole plants dry matter by 12.5 dt ha^{-1} was achieved in comparison with plots where no nitrogen fertilization was applied.

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REAKCJA DWÓCH TYPÓW ODMIAN KUKURYDZY WYRAŻONA PLONAMI SUCHEJ MASY W ZALEŻNOŚCI OD POZIOMU NAWOŻENIA AZOTEM I SPOSOBU APLIKACJI MAGNEZU

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Streszczenie. Doświadczenie polowe przeprowadzono w Zakładzie Dydaktyczno-Doświadczalnym w Swadzimiu koło Poznania w latach 2004-2007. Doświadczenie prowadzono w układzie „split-plot" z 3 czynnikami w 4 powtórzeniach. Badano 2 odmiany, 6 dawek azotu oraz dawki magnezu (sposób ich aplikacji). Oceniano wpływ tych czynników na plon suchej masy roślin kukurydzy oraz jej zawartość w fazie 5-6 liści oraz podczas zbioru. Lepszą dynamiką gromadzenia suchej masy w początkowej fazie rozwojowej charakteryzował się mieszaniec LG 2244 (typ stay-green), w stosunku do odmiany Anjou 258. Podczas zbioru ta zależność była odwrotna. Wielkość dawki azotu modyfikowała plony suchej masy kukurydzy w całym okresie jej wzrostu. Zastosowanie nawożenia magnezem powodowało wzrost plonu suchej masy słomy, kolb i całych roślin. Bardziej efektywnym sposobem aplikacji magnezu był wysiew rzutowy niż rzędowy.

Słowa kluczowe: typy odmian, azot, magnez, sposób aplikacji nawozu