Nauka Przyroda Technologie

2008
Tom 2
Zeszyt 3

Dział: Rolnictwo
ISSN 1897-7820 http://www.npt.up-poznan.net/tom2/zeszyt3/art_19.pdf
Copyright ©Wydawnictwo Uniwersytetu Przyrodniczego w Poznaniu

PIOTR SZULC, HUBERT WALIGÓRA, WITOLD SKRZYPCZAK

Department of Soil and Plant Cultivation
Poznań University of Life Sciences

BETTER EFFECTIVENESS OF MAIZE FERTILIZATION WITH NITROGEN THROUGH ADDITIONAL APPLICATION OF MAGNESIUM AND SULPHUR

Summary. Studies were carried out in order to investigate the effect of maize fertilization with magnesium sulphate and elementary sulphur. No effect of fertilizer combinations was found on the quantitative status of plants after germination and before harvest, on grain moisture and on the assimilation surface area of a single plant and on the leaf area index (LAI). In result of maize fertilization with NPK and Mg plus S, a significant increase of maize yield was found in comparison with the object fertilized with NPK only. The fertilization of maize with magnesium and sulphur increased the mass pf 1000 seeds and the number of grains in one cob. Better nutrition of maize caused a significant increase of maize infestation by frit fly and European corn borer.

Key words: maize, nitrogen, sulphur, magnesium, pests

Introduction

The basic aspect of a balanced agriculture is a balanced fertilization which should take into consideration all nutritive components indispensable for a correct growth and development of plants. The insurance of the optimal level of plant growth including the availability of nutritive agents guaranties the realization of plant yield-creating potential. Maize takes up from the soil significant amounts of nutritive components, particularly of nitrogen which is one of the most yield-creating macrocomponents (GRZEBISZ 2002, JANKOWIAK et AL. 1997). The utilization of this component depends in a high degree on the balancing of nitrogen dose with the dose of sulphur (GRZEBISZ and GAJ 2007, SEIDLER and MAMZER 1994, WYSZKOWSKI 2000, 2001).

The hypothesis of our experiment assumed that magnesium and sulphur, whose deficit exists in the majority of soils in Poland, may exert an effect on the yield of extensively produced plants including maize and additionally it can also improve the proper utilization of nitrogen supplied with the fertilizers. For the above reasons, studies were undertaken to investigate the effect of maize fertilization with a magnesium-and-sulphur fertilizer and elementary sulphur on the yielding of maize grown for grain.

Material and methods

Field studies were carried out in the Experimental and Didactic Farm at Swadzim near Poznań in the years 2004-2005. Experiment was established in a "split-plot" design with one experimental factor on five different levels. Fertilization with N, P and K was carried out before maize sowing in the following doses: 120 kg N, 80 kg P_2O_5 (35.2 kg P) and 120 kg K_2O (99.6 kg K) per 1 ha. Magnesium and sulphur were also sown before maize sowing in the form of kieserite (25% MgO, 50% SO_3 – 20% S, sulphate sulphur) and elementary sulphur (100% S), according to the schedule of experiment shown in Table 1. In the experiment, the maize hybrid 'Anjou 258' was used. Maize sowing was done with the use of a single-seed drill Monosem at the depth of 5-6 cm. Harvest of maize for grain was carried out with a plot combine-harvester. Results of one year studies were analysed with univariate analysis of variance followed by a synthesis of multiple experiments. The significance of differences was estimated at the level of $\alpha = 0.05$. The assimilation surface area of a single plant was calculated on the basis of the formula introduced by BOROWIECKI and FILIPIAK (1992).

Table 1. Maize fertilization combinations (kg/ha)
Tabela 1. Kombinacje nawożenia kukurydzy (kg/ha)

Factor level	N	P_2O_5	K_2O	MgO	S
NPK	120	80	120	–	–
NPK + 25 kg MgO + 20 kg S	120	80	120	25	20 (sulphate S)
NPK + 50 kg MgO + 40 kg S	120	80	120	50	40 (sulphate S)
NPK + 20 kg S	120	80	120	–	20 (elementary S)
NPK + 40 kg S	120	80	120	–	40 (elementary S)

Experiment was carried out on a grey-brown podsolic soil of light loamy sand type lying on light loam belonging to a good rye complex. Soil abundance in nutritive components and soil acidity are shown in Table 2.

Thermal and moisture conditions during vegetation in the years of experiments were favourable for the growth and development of maize. Sum of rainfalls in the period: April-September amounted to 301.0 mm in 2004 and 305.4 mm in 2005. Insignificant moisture deficits in the soil were found in the period of maize sowing (April 2004, April 2005 and in June 2005) (Fig. 1).

Table 2. Soil conditions at Swadzim
Tabela 2. Warunki glebowe w Swadzimiu

Specification	Years	
	2004	2005
N-NH_4 (mg/kg of dry mass of soil)	1.3	1.2
N-NO_3 (mg/kg of dry mass of soil)	4.5	3.1
P (mg P_2O_5 per 1 kg of soil)	125.0	164.0
P (mg P per 1 kg of soil)	55.0	72.0
K (mg K_2O per 1 kg of soil)	146.0	207.0
K (mg K per 1 kg of soil)	121.0	172.0
Mg (mg Mg per 1 kg of soil)	95.0	56.0
pH_{KCl}	5.87	5.55

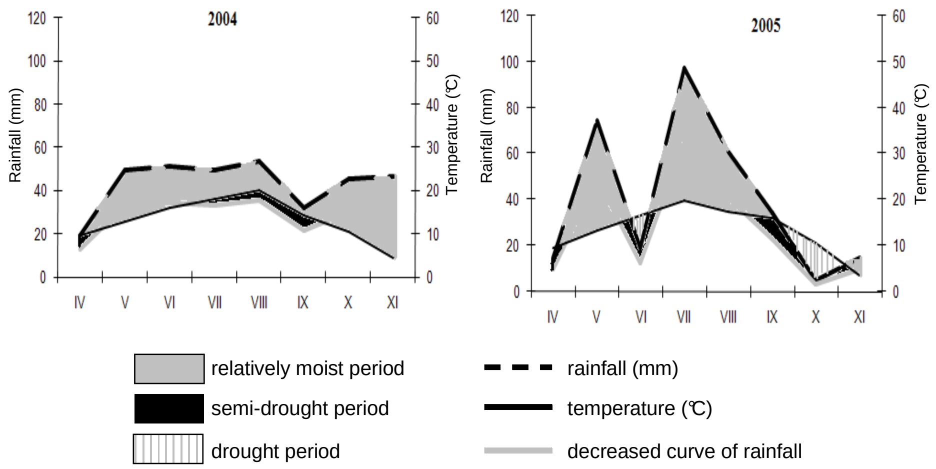

Fig. 1. Weather conditions in Experimental and Didactic Farm at Swadzim from April to November in the years 2004-2005
Rys. 1. Warunki meteorologiczne w ZDD w Swadzimiu od kwietnia do listopada w latach 2004-2005

Results and discussion

On the average, for the period of two years of studies, none of the factor levels did exert any significant effect on the quantitative value of plants either after germination or before harvest (Table 3). Losses of plants during maize vegetation were very small amounting from 0.0% to 1.89% (Table 3).

Table 3. Plant density (2004-2005)
Tabela 3. Obsada roślin (2004-2005)

Factor level	After germination (pcs/m)	Before harvest (pcs/m)	Losses (%)
NPK	6.87	6.74	1.89
NPK + 25 kg MgO + 20 kg S	6.85	6.79	0.87
NPK + 50 kg MgO + 40 kg S	7.00	6.93	1.00
NPK + 20 kg S	6.71	6.71	0.00
NPK + 40 kg S	6.39	6.29	1.56
$LSD_{0.05}$	n.s.	n.s.	n.s.

n.s. – non significant differences.

In the studies, the lowest yield of grain was obtained on objects fertilized only with NPK (68.41 dt/ha, Table 4). With an additional use of magnesium and sulphate sulphur and elementary sulphur, a significant increase of maize yielding was obtained (from 5.7% to 10.7%) as compared with the object fertilized with NPK only (Table 4). Definitely the highest grain yield (amounting to 75.76 dt/ha) was obtained with the fertilizer combination: NPK + 25 kg MgO and 20 kg S (sulphate sulphur). As reported by GRZEBISZ and HÄRDTER (2006), the basic yield-creating task of magnesium and sulphur is the increase of grain yield thanks to a better utilization of nitrogen fertilizer. Both these mineral components balance nitrogen effectively and permit to increase significantly the utilization of nitrogen fertilizer. Result obtained in our own studies indicated that a higher yielding of maize grown for grain when it is fertilized with sulphur, agrees with the reports in our local and in foreign literature (FOTYMA 2003, SCHNUG et AL. 1993, ZHANG et AL. 1999). The use of fertilizers with elementary sulphur is preferred on soils exposed to significant washout of it (HANEKLAUS et AL. 2000). Field experiment

Table 4. Grain yield and its moisture (2004-2005)
Tabela 4. Plon ziarna oraz jego wilgotność (2004-2005)

Factor level	Grain yield (dt/ha)	Grain yield increase (%)	Grain moisture (%)
NPK	68.41	100.0	34.15
NPK + 25 kg MgO + 20 kg S	75.76	110.7	33.95
NPK + 50 kg MgO + 40 kg S	72.29	105.7	34.30
NPK + 20 kg S	74.15	108.4	34.95
NPK + 40 kg S	73.22	107.0	34.50
$LSD_{0.05}$	3.214	–	n.s.

n.s. – non significant differences.

was carried out on a soil susceptible to nutritive components outwashing, hence the slow release of sulphates from the fertilizer containing elementary sulphur was advantageous in such conditions. This can also explain the increase of the yielding of maize which was fertilized with elementary sulphur as compared with the object fertilized with NPK.

The studied levels of fertilization did not exert any significant effect on the speed of maize ripening. Only a small delay in maize ripening was recorded which was demonstrated by insignificantly higher moisture of the grain harvested from objects fertilized with elementary sulphur (Table 4).

The yield of maize grain is expressed by the particular elements of its structure: the number of cobs, number of grains in one cob and the mass of 1000 seeds. In our own studies, independently of the weather course in the experimental years, a significant effect of the particular fertilization levels on the mass of 1000 seeds and on the number of grains in one cob was found (Table 5). The significantly smallest mass of 1000 seeds and the least number of grains in one cob were obtained on object where maize was fertilized with NPK only. When maize was additionally fertilized with magnesium and sulphate sulphur and elementary sulphur, higher values of these features were obtained in comparison with the object fertilized with NPK only. As reported by GRZEBISZ and HÄRDTER (2006), in the phase of grain development, there occurs a very close connection between magnesium content in the grain and the mass of 1000 seeds. Therefore, the correct nutrition of maize with magnesium exerts an influence on the increase of the mass of 1000 seeds expressed by a measurable effect of the final yield. The above mentioned dependence has been also confirmed by the correlation coefficients between grain yield and the elements of its structure. In our experiments, the grain yields depended most strongly on the mass of 1000 seeds and on the number of grains in one cob (Table 6). On the other hand, no effect was found to be exerted by the number of the produced cobs on the value of maize grain yield.

The shortest and at the same time the thinnest cobs were developed in maize fertilized by NPK only (Table 7). Additional application of magnesium and sulphur increased in a significant way the values of these features.

Table 5. Structure of grain yield (2004-2005)
Tabela 5. Struktura plonu ziarna (2004-2005)

Factor level	Number of cobs per 1 m^2	Mass of 1000 seeds (g)	Number of grains in one cob
NPK	6.70	318.2	463.7
NPK + 25 kg MgO + 20 kg S	6.71	334.1	487.9
NPK + 50 kg MgO + 40 kg S	6.66	323.7	491.2
NPK + 20 kg S	6.66	335.5	487.5
NPK + 40 kg S	6.23	329.7	491.2
$LSD_{0.05}$	n.s.	10.529	20.031

n.s. – non significant differences.

Szulc P., Waligóra H., Skrzypczak W., 2008. Better effectiveness of maize fertilization with nitrogen through additional application of magnesium and sulphur. Nauka Przyr. Technol. 2, 3, #19.

Table 6. Correlation coefficients of grain yield and the elements of yield structure (2004-2005)
Tabela 6. Współczynniki korelacji plonu ziarna i elementów struktury plonu (2004-2005)

Number of cobs	Mass of 1000 seeds	Number of grains in one cob
0.01	0.86*	0.83*

*Significance at P = 0.01.

Table 7. Morphological features of cobs (2004-2005)
Tabela 7. Cechy morfologiczne kolb (2004-2005)

Factor level	Cob length (cm)	Cob diameter (cm)
NPK	17.32	3.98
NPK + 25 kg MgO + 20 kg S	18.02	4.15
NPK + 50 kg MgO + 40 kg S	18.05	4.11
NPK + 20 kg S	18.35	4.17
NPK + 40 kg S	17.96	4.15
$LSD_{0.05}$	0.552	0.109

Correct distribution of plants on area unit exerts also a strong effect on the size of the assimilation surface area of plants, which decides in a high degree about the effectiveness of the proper utilization of solar radiation (SZELEŹNIK 1991). Excessive density of plants leads to a decreased productivity of photosynthesis which results in consequence of mutual shadowing of the plants (BOROWIECKI and MACHUL 1997). On the other hand, significantly decreased density of plants, in spite of better growth conditions for the particular plants, does not always lead to high yields. In our own studies, no significant effect of the particular fertilization combinations on the size of the assimilation surface area of a single plant was found (Table 8).

Table 8. Leaf surface area and Leaf Area Index (LAI) (2004-2005)
Tabela 8. Powierzchnia liści oraz wskaźnik LAI (2004-2005)

Factor level	Leaf area of 1 plant (cm^2)	Leaf Area Index
NPK	4 316.3	2.91
NPK + 25 kg MgO + 20 kg S	4 467.5	3.03
NPK + 50 kg MgO + 40 kg S	4 426.0	2.96
NPK + 20 kg S	4 388.8	2.94
NPK + 40 kg S	4 362.8	2.74
$LSD_{0.05}$	n.s.	n.s.

n.s. – non significant differences.

Shortage of sulphur impedes the plant growth rate, but differently than in case of magnesium, the depression affects in a higher degree the aboveground plant organs than the roots. Negative effects of plant malnutrition with Mg and S lead to the decrease of photosynthesis processes and to smaller stomata activity causing in final effect the growth reduction of the whole plant, primarily affecting the leaf blades (GRZEBISZ and HÄRDTER 2006).

Assimilation ability of plants is determined by LAI index. It shows the summary proportion of leaf blade area to the surface area of soil in which the plants grow. As reported by BROWN et AL. (1970), the highest yields of grain can be obtained when LAI value is 3.3. In turn, DUBAS (1988) reported that in maize cultivated for grain, the LAI should be 3.5-4.0. According to MENGEL and KIRKBY (1983), the optimal LAI value is 5. In our own studies, no effect of any fertilization combination was found to be exerted on this index. It must be stressed, however, that the value of our LAI was definitely lower than those quoted both in our local or foreign literature.

Maize is a plant which in comparison with other cultivated plants is attacked by pests in a comparatively small degree. Nevertheless, in favourable meteorological conditions for pests occurrence in the vegetative period, their feeding on maize can show to be significant (ADAMCZEWSKI et AL. 1997). This follows from the fact that because of a small plant density on the area unit, mass occurrence of pests decreases the yield-creating possibilities of plants.

In our studies, we have found the occurrence of frit fly (*Oscinella frit* L.) and the European corn borer (*Pyraustia nubilalis* L.) (Table 9). The extent of feeding by these two pests depended on the particular fertilizer combinations. The greatest occurrence of these pests was found in maize fertilized with NPK + 25 kg MgO and 20 Kg S (sulphate sulphur). The occurrence percentage for frit fly was 5.11% and for the European corn borer – 8.11%. Frit fly showed the lowest occurrence in maize fertilized with NPK + 40 kg S (elementary sulphur) – 1.73%, while European corn borer occurred in 3.05% on objects fertilized with NPK only (Table 9).

Table 9. Pests (2004-2005)
Tabela 9. Szkodniki (2004-2005)

Factor level	Frit fly		European corn borer	
	%	Bliss' °	%	Bliss' °
NPK	2.97	9.82	3.05	10.05
NPK + 25 kg MgO + 20 kg S	5.11	13.05	8.11	16.29
NPK + 50 kg MgO + 40 kg S	3.62	10.93	6.85	14.95
NPK + 20 kg S	3.81	11.20	4.61	12.07
NPK + 40 kg S	1.73	6.54	5.45	13.31
$LSD_{0.05}$	–	2.228	–	4.801

Szulc P., Waligóra H., Skrzypczak W., 2008. Better effectiveness of maize fertilization with nitrogen through additional application of magnesium and sulphur. Nauka Przyr. Technol. 2, 3, #19.

Conclusions

1. Application of magnesium with sulphur and elementary sulphur caused a significant increase of maize grain yield in comparison with the object where these components were not used. The grain yield increase amounted from 5.7% to 10.7%.

2. Mass of 1000 seeds, number of grains in one cob, cob length and its diameter were significantly greater in maize fertilized with Mg and S.

3. In the particular fertilizer combinations, no significant effect was found on the quantity of plants, their moisture, leaf surface area and on LAI.

4. Better nutrition of maize with nitrogen by the application of Mg and S caused higher occurrence of pests on maize plantations.

References

ADAMCZEWSKI K., SKRZYPCZAK G., LISOWICZ F., BUBNIEWICZ P., 1997. Aktualne problemy ochrony kukurydzy w Polsce. Zesz. Probl. Post. Nauk Roln. 450: 63-78.

BOROWIECKI J., FILIPIAK K., 1992. Wybór liści wskaźnikowych do określenia powierzchni liściowej kukurydzy. Pam. Puław. 100: 77-85.

BOROWIECKI J., MACHUL M., 1997. Stan badań nad agrotechniką kukurydzy w Polsce. Zesz. Probl. Post. Nauk Roln. 450: 55-62.

BROWN R.H., BEATY E.R., ETHREDGE W.J., HAYES D.D., 1970. Influence of row width and plant population on yield of two varieties of corn (*Zea mays* L.). Agron. J. 62: 767-770.

DUBAS A., 1988. Obsada roślin a produkcyjność kukurydzy. In: Obsada a produktywność roślin uprawnych. Konferencja Naukowa, Puławy, 8-9 listopada 1988. Cz. I. Referaty. IUNG & PAN, Puławy: 112-120.

FOTYMA E., 2003. Wpływ nawożenia siarką na wykorzystanie azotu z nawozów mineralnych przez rośliny uprawy polowej. Nawozy Nawoż. 4: 117-136.

GRZEBISZ W., 2002. Proekologiczne i efektywne ekonomicznie technologie nawożenia kukurydzy na ziarno. Materiały szkoleniowe. DWODR, Świdnica.

GRZEBISZ W., GAJ R., 2007. Zintegrowany system nawożenia kukurydzy. In: Integrowana produkcja kukurydzy. Eds. Z. Kaniczuk, S. Pruszyński. IOR, Poznań: 19-24.

GRZEBISZ W., HÄRDTER R., 2006. Kizeryt – naturalny siarczan magnezu w produkcji roślinnej. K&S, Kassel.

HANEKLAUS S., BLOEM E., SCHNUG E., 2000. Sulphur in agroecosystems. Folia Univ. Agric. Stetin. 2004, Agric. 81: 17-31.

JANKOWIAK J., KRUCZEK A., FOTYMA E., 1997. Efekty nawożenia mineralnego kukurydzy na podstawie wyników badań krajowych. Zesz. Probl. Post. Nauk Roln. 450: 79-116.

MENGEL K., KIRKBY A.E., 1983. Podstawy żywienia roślin. PWRiL, Warszawa.

SCHNUG E., HANEKLAUS S., MURPHY D., 1993. Impact of sulphur fertilization on fertilizer nitrogen efficiency. Sulphur Agric. 17: 8-12.

SEIDLER M., MAMZER M., 1994. Wpływ zróżnicowanego nawożenia magnezem na zawartość chlorofilu w liściach, natężenie fotosyntezy oraz wielkość i strukturę plonu kukurydzy. Biul. Magnezol. 5: 32-35.

SZELEŹNIK E., 1991. Kształtowanie się powierzchni liściowej kukurydzy w zależności od obsady roślin. Fragm. Agron. Zesz. Spec. 2: 141-150.

WYSZKOWSKI M., 2000. Reakcja kukurydzy na nawożenie magnezem stosowane we współdziałaniu z azotem, fosforem i potasem. Biul. Magnezol. 5, 2: 112-123.

WYSZKOWSKI M., 2001. Wpływ magnezu na kształtowanie plonów i wzajemnych relacji między niektórymi jonami w roślinach. Rozpr. Monogr. UW-M 52.

ZHANG Z., SUN K., LU A., 1999. Study on the effect of sulphur fertilizer application on crop and the balance of sulphur in soil. J. Henan Agricult. Sci. 5: 25-27.

POPRAWA EFEKTYWNOŚCI NAWOŻENIA KUKURYDZY AZOTEM POPRZEZ DODATKOWE ZASTOSOWANIE MAGNEZU I SIARKI

Streszczenie. Przeprowadzone badania miały na celu poznanie wpływu nawożenia kukurydzy nawozem magnezowo-siarkowym oraz siarką elementarną. Nie stwierdzono wpływu poszczególnych kombinacji nawozowych na stan ilościowy roślin po wschodach i przed zbiorem, na wilgotność ziarna oraz na powierzchnię asymilacyjną pojedynczej rośliny i wskaźnik LAI. W wyniku nawożenia kukurydzy NPK oraz Mg i S uzyskano istotny wzrost jej plonowania w stosunku do obiektu z wyłącznym nawożeniem NPK. Nawożenie kukurydzy magnezem i siarką powodowało wzrost masy 1000 nasion i liczby ziaren w kolbie. Lepsze odżywienie kukurydzy powodowało istotny wzrost żerowania ploniarki zbożówki i omacnicy prosowianki.

Słowa kluczowe: kukurydza, azot, siarka, magnez, szkodniki

Corresponding address – Adres do korespondencji:
Piotr Szulc, Katedra Uprawy Roli i Roślin, Uniwersytet Przyrodniczy w Poznaniu, ul. Mazowiecka 45/46, 60-623 Poznań, Poland, e-mail: pszulc@up.poznan.pl

Accepted for print – Zaakceptowano do druku:
8.07.2008

For citation – Do cytowania:
Szulc P., Waligóra H., Skrzypczak W., 2008. Better effectiveness of maize fertilization with nitrogen through additional application of magnesium and sulphur. Nauka Przyr. Technol. 2, 3, #19.