# POLISH JOURNAL OF NATURAL SCIENCES

Abbrev.: Pol. J. Natur. Sc., Vol 25(4): 323-331, Y. 2010

DOI 10.2478/v10020-010-0029-3

# THE EFFECT OF MULTI-COMPONENT FERTILIZERS ON SPRING WHEAT YIELD, THE CONTENT AND UPTAKE OF MACRONUTRIENTS\*

# Anna Nogalska, Jerzy Czapla, Małgorzata Skwierawska

Department of Agricultural Chemistry and Environmental Protection University of Warmia and Mazury in Olsztyn

Key words: spring wheat, yield, macronutrients, multi-component fertilizers.

### Abstract

The aim of this study was to determine the effect of mixed multi-component fertilizers on spring wheat yield, the content and uptake of macronutrients. A three-year field experiment (2005–2007) was carried out in a randomized block design at the Research and Experimental Station in Tomaszkowo, at the University of Warmia and Mazury in Olsztyn. The experiment comprised three fertilization treatments in four replications: control treatment (simple fertilizers), Amofosmag 3 and Amofosmag 4. The tested crop was spring wheat cv. Eta.

The application of Amofosmag 4 significantly increased the yield of spring wheat grain and straw. The concentrations of the analyzed macronutrients in wheat were similar in all fertilization treatments, thus pointing to a comparable effect of the applied fertilizers. More pronounced differences in the chemical composition of wheat plants were observed between successive years of the study. The highest total uptake of nitrogen, phosphorus, calcium and magnesium by spring wheat was noted in plots fertilized with Amofosmag 4, which indicates that the nutrients contained in this product were more readily available to plants.

# WPYW NAWOZÓW WIELOSKŁADNIKOWYCH NA PLON, ZAWARTOŚĆ I POBRANIE MAKROSKŁADNIKÓW PRZEZ PSZENICĘ JARĄ

### Anna Nogalska, Jerzy Czapla, Małgorzata Skwierawska

Katedra Chemii Rolnej i Ochrony Środowiska Uniwersytet Warmińsko-Mazurski w Olsztynie

Słowa kluczowe: pszenica jara, plon, makroskładniki, nawozy wieloskładnikowe.

Address: Anna Nogalska, University of Warmia and Mazury, ul. Michała Oczapowskiego 8, 10-719 Olsztyn, Poland, phone: +48 (89) 523 32 50, e-mail: anna.nogalska@uwm.edu.pl

<sup>\*</sup> This study was financed by Agrochem Ltd., Dobre Miasto.

### Abstrakt

Celem pracy była ocena wpływu zastosowanych nawozów wieloskładnikowych mieszanych na plon, zawartość i pobranie makroskładników przez pszenicę jarą. Trzyletnie doświadczenie polowe (2005–2007) przeprowadzono w Zakładzie Dydaktyczno-Doświadczalnym w Tomaszowie należącym do Uniwersytetu Warmińsko-Mazurskiego w Olsztynie. Doświadczenie, założone metodą losowanych bloków, obejmowało trzy obiekty nawozowe w czterech powtórzeniach: obiekt kontrolny (nawozy jednoskładnikowe), Amofosmag 3 i Amofosmag 4. Rośliną testowaną była pszenica jara odmiany Eta.

Z przeprowadzonych badań wynika, że nawożenie Amofosmagiem 4 miało istotny wpływ na zwiększenie plonu ziarna i słomy pszenicy jarej. Zawartość badanych makroskładników w pszenicy w poszczególnych obiektach nawozowych była zbliżona, a zastosowane nawozy wykazywały działanie równorzędne. Większe zróżnicowanie w składzie chemicznym badanej rośliny wystąpiło między poszczególnymi latami badań. Największe łączne pobranie azotu, fosforu, wapnia i magnezu przez pszenicę jarą stwierdzono w obiektach z Amofosmagiem 4. Świadczy to o lepszej przyswajalności składników pokarmowych z tego nawozu.

# Introduction

Due to their balanced and complete composition, mixed fertilizers can meet the specific nutrient requirements of each plant species and can be adjusted properly to soil fertility, which is an important consideration in developing fertilization programs. Multi-component fertilizers, which provide three primary macronutrients, N, P and K, and secondary nutrients, Mg, Ca, S and Na, in varying proportions, are applied to correct magnesium deficiency in the soil and to reduce sulfur emissions, thus preventing nutrient deficiency in plants (FILIPEK 2001, FILIPEK-MAZUR, GONDEK 2005). A clear advantage of multi-component fertilizers over simple fertilizers is that the former supply a combination of nutrients at a time (Glabisz et al. 1992). Compound fertilizers provide crops with essential nutrients in adequate amounts and proportions, and they help prevent or reduce nutrient leaching (CZUBA 1998, ZAWARTKA, SWIERAWSKA 2004a). The aim of this study was to determine the effect of mixed multi-component fertilizers, Amofosmag 3 and Amofosmag 4, on spring wheat yield, the content and uptake of macronutrients.

# **Materials and Methods**

A three-year field experiment (2005–2007) was carried out in a randomized block design at the Research and Experimental Station in Tomaszkowo, at the University of Warmia and Mazury in Olsztyn. The experiment, which comprised three fertilization treatments in four replications: control treatment (simple fertilizers), Amofosmag 3 and Amofosmag 4, was established on proper brown soil developed from sandy loam, of quality class III b and very good rye

complex. The physicochemical properties of soil in each year of the study are presented in Table 1. The tested crop was spring wheat (*Triticum aestivum* L. *mend*) cv. Eta. The preceding plants were winter triticale in the first year, and winter rapeseed in the following two years. Plot surface area was 10 m.

Selected physicochemical properties of soil used in the experiment (mg kg $^{-1}$ )

77	II 1 M IZOL	Available forms					
Year	pH w 1 M KCl	P	K	Mg			
2005	6.15	56.7	112.0	31.0			
2006	7.20	112.9	145.3	25.0			
2007	5.60	116.0	224.0	87.0			

Based on the average levels of available phosphorus in the soil, 300 kg ha<sup>-1</sup> Amofosmag 3 (NPKMg 3:14:20:2 + 22% CaO + 9% SO<sub>3</sub>; 9 kg N, 18 kg P, 50 kg K on pure ingredient basis) and Amofosmag 4 (NPKMg 4:15:15:2 + 24% CaO + 9% SO<sub>3</sub>; 12 kg N, 20 P, 37 kg K on pure ingredient basis) were applied pre-sowing. The nitrogen rate of 100 kg per ha was supplemented with two doses of ammonium nitrate applied by top-dressing in all treatments, including control. In the control treatment, the following fertilizers were applied presowing: 12 kg N in the form of urea, 45 kg  $P_2O_5$  (20 kg P) in the form of triple superphosphate and 45 kg  $P_3O_5$  (37 kg K): ha<sup>-1</sup> in the form of potash salt.

Samples of spring wheat were collected at the stage of full maturity. The grain and straw harvested in each plot was dried and weighed individually. Wet mineralized samples were assayed for the content of: total nitrogen – by the hypochlorite method, phosphorus – by the vanadium-molybdenum method, calcium and potassium – by atomic emission spectrometry (AES), and magnesium – by atomic absorption spectrometry (AAS). The results of chemical analyses were verified statistically by a two-factorial analysis of variance for a randomized block design. The experimental factors were as follows: a – fertilization, b – duration of the experiment. The least significant difference was assumed at p=0.05.

## **Results and Discussion**

The distribution of air temperatures in 2005 differed insignificantly from the long-term average (Table 2). Precipitation total in April was substantially lower than the long-term average, which could have contributed to uneven emergence, whereas July was too wet. In 2006, mean monthly temperatures were similar to the long-term average. The highest temperature was noted in July. Precipitation levels differed considerably from the average values in July and August. Precipitation total in July in August was over 2.5-fold lower and nearly 2.5-fold higher, respectively, than the long period average, which made harvest difficult. In 2007, air temperatures during the growing season were slightly above the long-term average. July was wet, with a difference of 99.9 mm between mean monthly rainfall and the long period average. Weather conditions could have affected the yield of spring wheat.

 ${\it Table~2}$  Weather conditions in 2005–2007 – data provided by the Meteorological Station in Tomaszkowo

Month	Mear	daily te	emperat	ure (°C)	Precipitation total (mm)			
	2005	2006	2007	1970–2000	2005	2006	2007	1970–2000
April	8.2	7.3	7.5	6.9	22.0	25.6	24.7	36.1
May	11.6	12.5	13.8	12.7	68.2	89.2	93.5	51.9
June	14.2	16.0	17.7	15.9	35.4	79.2	88.1	79.3
July	19.7	20.9	17.7	17.7	83.9	29.3	173.7	73.8
August	16.9	17.2	18.3	17.2	39.6	165.0	68.0	67.1
September	18.1	14.8	12.6	12.5	17.9	51.0	57.9	59.0

In the first year of the experiment (2005), the yield of spring wheat grain ranged from 4.38 to 4.86 t ha<sup>-1</sup>, depending on the applied fertilizer (Table 3). The highest average yield was attained in the treatment fertilized with Amofosmag 4 – it was by 7.8% and 11% higher than in the control treatment (simple fertilizers) and in the Amofosmag 3 treatment, respectively. In an experiment with winter wheat conducted by SZTUDER (2007), multi-component fertilizers had a more desirable yield-forming effect than simple fertilizers. Different results were reported by STEPIEN and MERCIK (2001). In the present study, wheat straw yield corresponded to grain yield. In 2006, the yield of spring wheat grain varied between 6.14 and 6.50 t ha<sup>-1</sup>, and it was considerably higher (by 37% on average) than the value noted in 2005. This could have resulted from favorable temperatures. Amofosmag 4 contributed to an increase in the yield of wheat grain and straw, in comparison with the remaining treatments. The lowest wheat grain yield was attained in 2007 - it was lower by 13.3% and 37% than in 2005 and 2006, respectively. The above could be due to less favorable weather conditions. Also in 2007 Amofosmag 4 had the most beneficial influence on wheat grain yield, which was found to increase signifi-

0.71

n.s.

cantly (by around 15%), compared with the control treatment and the treatment fertilized with Amofosmag 3. Wheat straw yield was affected by the applied fertilizers to a lower degree.

				_			_		
		Grain				Straw			
Treatment	2005	2006	2007	mean for $a$	2005	2006	2007	mean for a	
NPK	4.51	6.22	3.80	4.85	5.33	8.55	5.90	6.59	
Amofosmag 4	4.86	6.50	4.34	5.23	5.77	9.07	6.35	7.06	
Amofosmag 3	4.38	6.14	3.76	4.76	5.44	8.48	5.85	6.59	
Mean for b	4.58	6.29	3.97	-	5.51	8.70	6.03	-	
$LSD_{n=0.05}$ for $a$		0.39			·		n.s.		

0.42

n s

Table 3 Spring wheat yield after the application of Amofosmag 4 and Amofosmag 3 (t  $\rm ha^{-1})$ 

Legend: a – fertilization, b – duration of the experiment

b

 $a \cdot b$ 

Amofosmag 4 increased the yield of spring wheat grain and straw by approximately 8% and 10%, respectively, in comparison with the control treatment. An increase in the yield of spring barley grain following the application of mixed fertilizers was also reported by ZAWARTKA and SKWIERAW-SKA (2004b), and by MAZUR et al. (2001).

The results of chemical analyses of spring wheat grain and straw, presented in Table 4, show that the concentrations of the analyzed macronutrients varied insignificantly between fertilization treatments, and in most cases they remained within normal limits (CZUBA 1996). Significant differences were observed in this respect between successive years of the study. In the first year, the grain of spring wheat contained significantly less nitrogen and significantly more potassium and magnesium, compared with the values noted in the two consecutive years. In the second year of the experiment, wheat grain contained larger amounts of phosphorus and calcium than in the first and third year, and larger quantities of nitrogen than in the first year. The above differences were statistically significant. The highest nitrogen content (26.7 g kg<sup>-1</sup> d.m. on average) of wheat grain was observed in 2007, and it was significantly higher than in 2005 and 2006 (by 76% and 24%, respectively). Nevertheless, the findings of numerous authors (KRZYWY et al. 2000, FILIPEK 2001, KRZYWY et al. 2001, MAZUR et al. 2001) suggest that multi-component fertilizers have an insignificant effect on the macronutrient content of the tested plants.

Macronutrient uptake (kg per ha) was estimated based on the yield and macronutrient content of spring wheat grain and straw. The highest nitrogen ptake by wheat plants (177.19 kg N ha<sup>-1</sup>) was noted in the second year of the

Table 4 Macronutrient content of spring wheat after the application of Amofosmag 4 and Amofosmag 3  $\rm (g~kg^{-1}~d.m.)$ 

75			Grain				Straw			
Macronutrient	Treatment	2005	2006	2007	mean for $a$	2005	2006	2007	mean for $a$	
Nitrogen	NPK Amofosmag 4 Amofosmag 3	15.8 15.4 14.1	21.6 21.4 21.7	25.6 26.8 27.6	21.0 21.2 21.1	6.2 6.8 6.5	4.0 4.2 4.2	4.6 4.5 4.9	4.9 5.2 5.2	
Mean	for $b$	15,1	21.6	26.7		6.5	4.1	4.7		
$LSD_{p=0.05}$ for $a$				n.s.			ı	n.s.		
$\begin{bmatrix} b \\ a \end{bmatrix}$	· <i>b</i>			1.07 n.s.				0.79 n.s.		
Phosphorus	NPK Amofosmag 4 Amofosmag 3	4.2 4.1 4.2	5.7 5.7 5.9	2.6 2.5 2.6	4.2 4.1 4.2	0.5 0.5 0.6	1.1 1.1 1.1	0.9 0.8 0.8	0.8 0.8 0.8	
Mean	for b	4.2	5.8	2.6		0.5	1.1	0.8		
LSD <sub><math>p=0.05</math></sub> for $a$ $b$ $a$	· <i>b</i>			n.s. 0.21 n.s.				n.s. 0.20 n.s.		
Potassium	NPK Amofosmag 4 Amofosmag 3	5.3 5.5 5.4	3.3 3.1 3.3	4.0 3.7 3.8	4.2 4.1 4.2	13.1 12.4 13.0	6.8 5.9 6.3	10.5 11.1 10.8	10.1 9.8 10.0	
Mean	for b	5.4	3.2	3.8		12.8	6.3	10.8		
LSD <sub><math>p=0.05</math></sub> for $a$ $b$ $a$	· <i>b</i>			n.s. 0.24 n.s.				n.s. 1.07 n.s.		
Calcium	NPK Amofosmag 4 Amofosmag 3	0.39 0.45 0.40	1.00 1.01 1.02	0.43 0.45 0.44	0.61 0.64 0.62	2.8 2.8 2.5	2.5 2.3 2.2	1.6 1.5 1.6	2.3 2.2 2.1	
Mean	for b	0.41	1.01	0.44		2.7	2.3	1.6		
$LSD_{p=0.05} \text{ for } a \\ b \\ a \cdot b$				n.s. 0.05 n.s.				n.s. 0.42 n.s.		
Magnesium	NPK Amofosmag 4 Amofosmag 3	1.6 1.6 1.6	1.0 1.0 1.1	1.0 1.0 1.0	1.2 1.2 1.2	$0.43 \\ 0.41 \\ 0.40$	$0.58 \\ 0.55 \\ 0.56$	$0.48 \\ 0.48 \\ 0.46$	0.50 0.48 0.47	
Mean dla b		1.6	1.0	1.0		0.41	0.56	0.47		
$LSD_{p=0.05}$ for $a$ $b$ $a \cdot b$				n.s. 0.05 n.s.				n.s. 0.09 n.s.		

Explanations as in Table 3

experiment, following the application of Amofosmag 4. Nitrogen uptake was correlated with wheat yield (Table 5). Phosphorus uptake levels were comparable in all treatments, and they were found to increase in plots fertilized with Amofosmag 4. Phosphorus uptake varied between years, reaching the highest level in 2006 (44.85 to 47.02 kg P ha $^{-1}$ ) when the highest yield of wheat grain

	Table 5
Nutrient uptake by spring wheat grain and straw (kg ha <sup>-1</sup> )	

Treatment	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium					
2005										
NPK	104.6	21.4	94.4	16.8	9.4					
Amofosmag 4	114.4	22.7	98.3	18.3	10.1					
Amofosmag 3	96.9	21.5	94.4	15.3	9.2					
	2006									
NPK	168.5	44.8	78.7	27.6	11.2					
Amofosmag 4	177.2	47.0	73.7	27.4	11.5					
Amofosmag 3	174.8	45.5	73.7	24.8	11.5					
2007										
NPK	124.4	16.0	87.0	11.1	6.6					
Amofosmag 4	130.4	15.9	86.5	11.5	7.4					
Amofosmag 3	132.4	14.4	77.5	11.0	6.4					

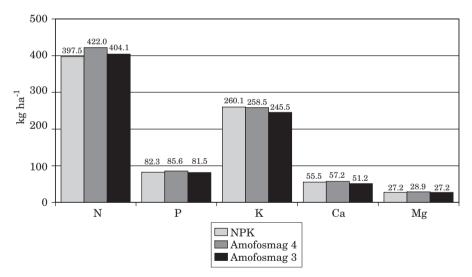


Fig. 1. Total macronutrient uptake by spring wheat over a three-year experimental period

and straw was obtained, and the lowest (around three-fold lower than in the preceding year) in 2007. A similar, albeit less pronounced, relation was observed with regard to the uptake of calcium and magnesium, which was highest after the application of Amofosmag 4. Potassium uptake by wheat plants was in the range of 73.66–98.27 kg K ha<sup>-1</sup>. The highest potassium uptake was reported in the first year of the experiment in the Amofosmag 4 treatment, and it was related to the high concentrations of this element in wheat grain and straw. In the long term, simple fertilizers improved potassium

uptake by spring wheat (Figure 1). The highest total uptake of nitrogen, phosphorus, calcium and magnesium by spring wheat (mean values of three years) was noted in plots fertilized with Amofosmag 4, which indicates that the nutrients contained in this product were more readily available to plants. Stepień and Mercik (2001), Świerczewska and Sztuder (2006), and Sztuder (2007) demonstrated that multi-component fertilizers, compared with simple fertilizers, contributed to higher nutrient uptake by various plants.

# **Conclusions**

- 1. Amofosmag 4 had the most beneficial influence on spring wheat yield the application of this fertilizer enabled to increase grain yield by 9% on average, in comparison with the remaining treatments.
- 2. The concentrations of the analyzed macronutrients in spring wheat grain and straw varied insignificantly between fertilization treatments. Simple and mixed multi-component fertilizers exerted a comparable effect on the mineral composition of the tested crop. Significant differences were observed in this respect between successive years of the study.
- 3. The highest total uptake of nitrogen, phosphorus, calcium and magnesium by spring wheat was noted in plots fertilized with Amofosmag 4, which indicates that the nutrients contained in this product were more readily available to plants.

Translated by Aleksandra Poprawska

Accepted for print 9.09.2010

# References

Czuba R. 1998. Optymalny asortyment podstawowych nawozów wieloskładnikowych warunkowany krajową strukturą zasiewów i zasobnością gleb. Folia Univ. Agric. Stetin., Agricultura, 190(72): 43-48.

Czuba R. 1996. Nawożenie mineralne roślin. Zakłady Chemiczne "POLICE" SA.

GLABISZ U., Kic B., Grzmil B. 1992. Manufacture of low chloride multicomponent fertilizers based on conversion in aqueous solution. J. Agric. Food Chem., 40: 1393–1397.

Krzywy E., Jakubowski W., Krzywy J. 2001. Wpływ nawozów wieloskładnikowych i jednoskładnikowych na wysokość i niektóre cechy jakościowe plonów roślin. Cz. I. Wpływ nawozów wieloskładnikowych i jednoskładnikowych na wysokość plonów roślin oraz zawartość w nich azotu, fosforu, potasu, wapnia, magnezu i siarki. Folia Univ. Agric. Stetin., Agricultura, 223(89): 99–106.

Krzywy E., Jakubowski W., Pasikowski J. 2000. Wpływ nawozów wieloskładnikowych i jednoskładnikowych na wysokość plonów i niektóre cechy jakościowe pszenżyta ozimego i jęczmienia jarego. Folia Univ. Agric. Stetin., Agricultura, 204(81): 163–168.

FILIPEK T. 2001. Zawartość składników pokarmowych a zastosowanie nawozów wieloskładnikowych z KIZPS "Siarkopol". Folia Univ. Agric. Stetin., Agricultura, 223(89): 41–46.

FILIPEK-MAZUR B., GONDEK K. 2005. Plonowanie i zawartość siarki w gorczycy białej jako efekt stosowania wieloskładnikowych nawozów zawierających siarkę. Acta Agrophysica, 6(2): 343–351.

- Mazur T., Mazur Z., Wojtas A., Grześkowiak A. 2001. Wpływ nawozów wieloskładnikowych na wielkość i jakość plonów roślin uprawianych w 4-polowym zmianowaniu. Folia Univ. Agric. Stetin., Agricultura, 223(89): 113–120.
- Stepień W., Mercik S. 2001. Działanie na rośliny i glebę nawozów wieloskładnikowych i pojedynczych w zmianowaniu pięciopolowym. Folia Univ. Agric. Stetin., Agricultura, 223(89): 165–168.
- Świerczewska M., Sztuder H. 2006. Wskaźniki efektywności i wykorzystania składników pokarmowych przy różnych sposobach aplikacji nawozów w uprawie kukurydzy. Zesz. Probl. Post. Nauk Rol., 508: 181–186.
- SZTUDER H. 2007. Produkcyjna i ekologiczna ocena różnych sposobów aplikacji nawozów w uprawie pszenicy ozimej. Inżynieria Rolnicza, 3(91): 167–172.
- Zawartka L., Skwierawska M. 2004a. Wpływ nawozów wieloskładnikowych na wymywanie fosforu i innych makroelementów z gleby. Prace Nauk. AE Wrocław, 1017: 69–77.
- ZAWARTKA L., SKWIERAWSKA M. 2004b. Wpływ nawozów wieloskładnikowych na plon i zawartość fosforu i innych makroelementów w jęczmieniu jarym. Prace Nauk. AE Wrocław, Chemia, 1017: 149–157.