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THE EFFECT OF MULTI-COMPONENT FERTILIZERS ON THE YIELD AND MINERAL COMPOSITION OF WINTER TRITICALE*

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Key words: winter triticale, yield, macronutrients, multi-component fertilizers, uptake.

Abstract

Multi-component fertilizers are increasingly used due to their easy application, solubility and complex composition. A clear advantage of multi-component fertilizers over simple fertilizers is that the former supply a combination of nutrients at a time. The objective of this study was to determine the effect of multi-component fertilizers, Amofosmag 4 and Amofosmag 3, on winter triticale yield, and the content and uptake of macronutrients. A three-year field experiment (2008–2010) 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 (NE Poland). The experiment comprised three fertilization treatments in four replications: control treatment (simple fertilizers) and two treatments with mixed multi-component fertilizers, Amofosmag 4 and Amofosmag 3. The tested crop was winter triticale cv. Grenado. Wet mineralized plant 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). In most cases, the application of Amofosmag 4 and Amofosmag 3 increased the yield of winter triticale grain and straw, in comparison with simple fertilizers. The concentrations of the analyzed macronutrients in triticale were similar in all fertilization treatments, thus pointing to a comparable effect of the applied fertilizers, except for the nitrogen content of triticale grain which was highest in plots fertilized with simple fertilizers, compared with the other treatments. Differences in the chemical composition of triticale plants were observed between successive years of the study. The highest total uptake of phosphorus, potassium and magnesium by winter triticale was noted in plots fertilized with Amofosmag 3. Nitrogen uptake was higher in the control treatment, and calcium uptake in the Amofosmag 4 treatment.

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WPŁYW NAWOZÓW WIELOSKŁADNIKOWYCH NA PLONOWANIE I SKŁAD MINERALNY PSZENŻYTA OZIMEGO

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S ł o w a k l u c z o w e: pszenżyto ozime, plon, makroelementy, nawozy wieloskładnikowe, pobranie.

A b s t r a k t

Nawozy wieloskładnikowe są coraz powszechniej stosowane ze względu na łatwość aplikacji, rozpuszczalność i kompleksowy skład pierwiastkowy. Możliwość wprowadzenia jednocześnie kilku składników czyni je konkurencyjnymi w porównaniu z jednoskładnikowymi. Celem pracy było zbadanie wpływu nawozów wieloskładnikowych Amofosmagu 4 i Amofosmagu 3 na plon, zawartość i pobranie makroskładników przez pszenżyto ozime. Trzyletnie doświadczenie polowe (2008–2010) przeprowadzono w Ośrodku Dydaktyczno-Doświadczalnym w Tomaszkowie należącym do Uniwersytetu Warmińsko-Mazurskiego w Olsztynie. Doświadczenie, założone metodą losowanych bloków, obejmowało trzy obiekty nawozowe w czterech powtórzeniach: obiekt kontrolny (nawozy jednoskładnikowe), Amofosmag 4 i Amofosmag 3. Rośliną testowaną było pszenżyto ozime odmiany 'Grenado'. W zmineralizowanych „na mokro" próbkach roślinnych oznaczono: azot ogólny – metodą podchlorynową, fosfor – metodą wanadowo-molibdenową, wapń i potas – metodą emisyjnej spektometrii atomowej (ESA) oraz magnez – metodą absorpcyjnej spektometrii atomowej (ASA). Z przeprowadzonego doświadczenia wynika, że nawożenie Amofosmagiem 4 i Amofosmagiem 3 miało na ogół wpływ na zwiększenie plonu ziarna i słomy pszenżyta ozimego w porównaniu z nawozami jednoskładnikowymi. Koncentracja badanych makroelementów w pszenżycie w poszczególnych obiektach nawozowych była na ogół zbliżona, zastosowane nawozy wykazywały działanie równorzędne. Wyjątek stanowiła zawartość azotu w ziarnie pszenżyta, gdzie po zastosowaniu nawozów jednoskładnikowych wystąpiła największa zawartość tego składnika w porównaniu z pozostałymi obiektami nawozowych. Zróżnicowanie w składzie chemicznym badanej rośliny wystąpiło między poszczególnymi latami badań. Największe łączne pobranie fosforu, potasu i magnezu przez pszenżyto ozime stwierdzono w obiektach z Amofosmagiem 3. Azot był nieco lepiej pobierany przez pszenżyto w obiekcie kontrolnym, zaś wapń – w obiekcie z Amofosmagiem 4.

Introduction

The use of multi-component mineral fertilizers, supplying a balanced mixture of major nutrients, allows to address environmental concerns in agricultural ecosystems (ŁABUDA 1994). Since the 1990s, there has been a steady increase in the share of multi-component fertilizers in total mineral fertilizer consumption. Numerous fertilizer manufacturers offer a wide variety and range of mixed fertilizers, blends and compound fertilizers (POTARZYCKI and LEWICKA 2002). Mineral fertilizers currently available on the market differ considerably with respect to quality and price. The most important characteristics of fertilizers include their easy application and storage, solubility and complex composition. 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 (ZAWARTKA and SKWIERAWSKA 2004a). Fertilization rates should be adapted to the requirements of a given plant species, and they have to be determined in view of crop yield and quality, fertilizer efficiency, and environmental issues.

The objective of this study was to determine the effect of mixed component fertilizers, Amofosmag 4 and Amofosmag 3, on winter triticale yield, and the content and uptake of macronutrients.

Materials and Methods

A three-year field experiment (2008–2010) 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 4 and Amofosmag 3, 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 winter triticale (*Triticosecale Wittm L.)* cv. Grenado. The preceding plants were winter triticale. Plot surface area was 10 m^2.

Table 1

Selected physicochemical properties of soil used in the experiment [mg kg^{-1}]

Year	pH w 1 M KCl	Available forms		
		P	K	Mg
2008	6.2	72	207	28
2009	7.0	84	149	35
2010	5.7	70	244	96

Based on the average levels of available phosphorus in the soil, 350 kg ha^{-1} Amofosmag 3 (NPKMg 3:14:20:2 + 22% CaO + 9% SO3: 10.5 kg N, 21.5 kg P, 58 kg K, 55 kg Ca, 4 kg Mg, 12.5 kg S on pure ingredient basis) and Amofosmag 4 (NPKMg 4:15:15:2 + 24% CaO + 9% SO3 : 12 kg N, 23 P, 43.5 kg K, 60 kg Ca, 4 kg Mg, 12.5 kg S on pure ingredient basis) were applied pre-sowing. The nitrogen rate of 80 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: 14 kg N in the form of urea, 23 kg P in the form of triple superphosphate and 43.5 kg K kg ha^{-1} in the form of potash salt.

Samples of winter triticale 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 the growing season of 2008 differed insignificantly from the long-term average (Table 2). Precipitation total in May and June was substantially lower than the multiannual average, which could have reduce the number and size of triticale ears. In 2009, mean monthly temperatures were similar to the long-term average. The highest temperature was recorded in July. April was relatively dry, while in June precipitation levels considerably exceeded the long-term average. In 2010, air temperatures during the growing season were slightly above the long-term average. Precipitation total in May was over 2.5-fold higher than the long period average. May was wet, with a difference of 80.0 mm between mean monthly rainfall and the long period average. Weather conditions could have affected the yield of winter triticale.

Table 2

Weather conditions in 2008–2010 – data provided by the Meteorological Station in Tomaszkowo

Month	Mean monthly temperature [°C]				Precipitation total [mm]			
	2008	2009	2010	1970–2000	2008	2009	2010	1970–2000
April	7.7	9.4	8.1	6.9	31.4	4.8	18.2	36.1
May	12.3	12.4	12.0	12.7	27.0	52.9	131.9	51.9
June	16.9	14.9	16.4	15.9	32.7	136.9	84.8	79.3
July	18.5	20.4	21.1	17.7	57.7	48.3	80.4	73.8
August	18.4	17.6	19.3	17.2	102.1	19.3	95.3	67.1
September	15.1	14.2	12.0	12.5	22.9	25.7	40.5	59.0

In 2008, the yield of winter triticale grain ranged from 9.90 to 10.57 t ha^{-1}, and it was not significantly affected by the type of fertilizers (Table 3). The highest average yield of winter triticale grain was noted in the Amofosmag 3 treatment. Straw yield corresponded to grain yield, and it was not significantly influenced by the fertilizers applied in the study. In an experiment with spring wheat conducted by NOGALSKA et al. (2010), multi-component fertilizers had a more desirable yield-forming effect than simple fertilizers. In the second year of the study (2009), the yield of winter triticale grain varied from 3.82 to 3.97 t ha^{-1}, and it was lower than in 2008 and 2010, which could be due to less favorable weather conditions. Precipitation total in April was very low, which could have reduce the number and size of triticale ears. As demonstrated by ALARU et al. (2003) and JACZEWSKA-KALICKA (2008), grain crops are highly sensitive to weather conditions. The experimental factors had no significant effect on straw yield. In the third year of the experiment (2010), Amofosmag 4 had the most beneficial influence on triticale grain yield, which was found to increase by around 7%, compared with the control treatment. Wheat straw yield was affected by the applied fertilizers to a lower degree.

Table 3

Winter triticale yield after the application of Amofosmag 4 and Amofosmag 3 [t ha $^{-1}$]

Treatment	Grain				Straw			
	2008	2009	2010	mean for *a*	2008	2009	2010	mean for *a*
NPK	10.04	3.82	6.94	6.93	8.94	7.54	7.76	8.08
Amofosmag 4	9.90	3.97	7.44	7.10	9.07	7.81	8.86	8.58
Amofosmag 3	10.57	3.91	7.28	7.25	9.04	8.73	8.72	8.82
Mean for *b*	10.17	3.90	7.22		9.01	8.02	8.44	
$LSD_{p=0,05}$ for *a*	n.s.				n.s.			
b	0.56				n.s.			
ab	n.s.				n.s.			

Explanations: *a* – fertilization, *b* – duration of the experiment, *ab* – interaction, n.s. – non-significant difference

The results of the present study show that Amofosmag 3 caused an approximately 5% and 9% increase (on average) in the yield of triticale grain and straw, respectively, compared with simple fertilizers. An increase in the yield of different cereal species in response to the application of mixed fertilizers was also reported by ZAWARTKA and SKWIERAWSKA (2004b), TRAWCZYŃSKI and SOCHA (2006) and NOGALSKA et al. (2010, 2011), whereas in an experiment by WINIARSKI et al. (2002) the yield-forming effects of multi-component and simple fertilizers were comparable.

Table 4

Macronutrient content of winter triticale after the application of Amofosmag 4 and Amofosmag 3 [g kg^{-1} d.m.]

Macro-nutrient	Treatment	Grain				Straw			
		2008	2009	2010	mean for *a*	2008	2009	2010	mean for *a*
Nitrogen	NPK	17.30	11.15	16.80	15.08	3.17	3.97	5.55	4,23
	Amofosmag 4	15.22	10.42	16.12	13.92	3.62	4.96	6.75	5,11
	Amofosmag 3	9.32	11.71	16.35	12.46	2.75	5.85	5.64	4,74
Mean for *b*		13,94	11.09	16.42		3.18	4.92	5.98	
$LSD_{p=0.05}$ for *a* *b* *ab*		1.285 1.299 2.226				n.s. 0.739 n.s.			
Phosphorus	NPK	1.79	4.81	3.86	3.48	1.04	2.65	1.67	1.78
	Amofosmag 4	1.77	5.47	3.74	3.66	1.08	2.72	1.79	1.86
	Amofosmag 3	1.73	4.76	3.89	3.46	1.07	3.07	1.67	1.93
Mean for *b*		1.76	5.01	3.83		1.06	2.81	1.71	
$LSD_{p=0.05}$ for *a* *b* *ab*		n.s. 0.359 n.s.				n.s. 0.282 n.s.			
Potassium	NPK	3.82	5.75	5.47	5.01	14.85	17.22	22.40	18.15
	Amofosmag 4	3.47	5.95	5.24	4.88	13.90	13.80	19.34	15.68
	Amofosmag 3	3.70	5.85	5.60	5.05	13.85	15.70	22.63	17.39
Mean for *b*		3.66	5.84	5.43		14.20	15.57	21.45	
$LSD_{p=0.05}$ for *a* *b* *ab*		n.s. 0.309 n.s.				1.511 1.600 n.s.			
Calcium	NPK	0.72	0.62	0.79	0.71	5.78	2.50	4.25	4.17
	Amofosmag 4	0.73	0.67	0.75	0.71	6.06	2.65	4.07	4.26
	Amofosmag 3	0.72	0.63	0.93	0.76	4.69	2.47	4.16	3.77
Mean for *b*		0.72	0.64	0.82		5.51	2.54	4.16	
$LSD_{p=0.05}$ for *a* *b* *ab*		n.s. 0.111 n.s.				n.s. 0.537 n.s.			
Magnesium	NPK	0.85	0.94	0.88	0.89	0.41	0.49	0.44	0.44
	Amofosmag 4	0.82	0.95	0.89	0.88	0.43	0.58	0.43	0.48
	Amofosmag 3	0.92	0.94	0.87	0.91	0.39	0.63	0.37	0.46
Mean dla *b*		0.86	0.94	0.88		0.41	0.56	0.41	
$LSD_{p=0.05}$ for *a* *b* *ab*		n.s. 0.066 n.s.				n.s. 0.035 0.061			

Explantations as in Table 3

Triticale is used as a feed grain, therefore its macronutrient content is equally important as yield. Cereal grains serve as the main source of mineral substances for animals (BRZOZOWSKA 2006). The results of chemical analyses of winter triticale grain and straw (Table 4) suggest that the concentrations of the analyzed macronutrients varied between the years of the study. In 2008, the nitrogen content of winter triticale grain ranged from 9.32 to 17.30 g kg DM, and it was highest in the control treatment. The lowest nitrogen content of triticale kernels was noted in 2009, and the highest nitrogen concentrations in triticale grain (16.42 g kg^{-1} DM) were observed in 2010. In a study by GROMOVA and POLACK (1995), the average nitrogen content of triticale grain was 23.70 g kg^{-1} DM. The applied fertilizers had no influence on nitrogen concentrations in triticale straw. The highest nitrogen content of triticale straw was reported in the third year of the experiment, in the Amofosmag 4 treatment.

In 2008, triticale grain contained significantly less phosphorus and potassium than in 2009 and 2010. In the second and third year of the experiment, triticale kernels were more abundant in phosphorus and potassium (significant differences). The calcium content of winter triticale grain and straw was not determined by the type of fertilizers. Differences between treatments were minor. The lowest calcium concentrations in triticale grain were noted in 2009. The magnesium content of winter triticale remained stable throughout the experiment, reaching the highest level in the second year. The findings of numerous authors (FILIPEK 2001, TRAWCZYŃSKI and GRZEŚKIEWICZ 2006, MAZUR et al. 2001, NOGALSKA et al. 2010, 2011) indicate that multi-component fertilizers have no significant effect on the macronutrient content of tested plant species.

Macronutrient uptake was estimated based on the yield and macronutrient content of winter triticale grain and straw. The highest nitrogen uptake by winter triticale plants (215.92 kg N ha^{-1}) was noted in the first year of the experiment, in the control treatment (Table 5). Nitrogen uptake was correlated with the percentage content of nitrogen in plants (Table 4). Similar results were reported by FOSSATI et al. (1993). Nitrogen uptake was substantially lower in the second year of the study. A similar, albeit less pronounced, trend was noted with regard to calcium and magnesium concentrations. Phosphorus uptake levels were comparable in all treatments, and they tended to increase in response to Amofosmag 3. Phosphorus uptake varied considerably between years, due to differences in triticale yield and the percentage content of macronutrients. Phosphorus uptake was highest in 2009 (38.35–45.41 kg P ha^{-1}), and lowest in 2008 (over two-fold lower than in 2009 and 2010) when triticale kernels were least abundant in phosphorus. Potassium uptake by winter triticale plants was highest in the third year of the experiment, in particular after the application of Amofosmag 3. Such a trend was also observed with respect o the total potassium uptake (Figure 1). The highest total (mean values of three years) nitrogen uptake was noted in the control treatment (Figure 1). The highest uptake of phosphorus, potassium and magnesium was observed in treatments with Amofosmag 3, while the highest calcium uptake was observed in the Amofosmag 4 treatment. Partially different results were reported by NOGALSKA et al. (2010, 2011).

Table 5

Nutrient uptake by winter triticale grain and straw [kg ha^{-1}]

Treatment	Nitrogen	Phosphorus	Potassium	Calcium	Magnesium
2008					
NPK	215.92	27.26	171.10	58.59	12.19
Amofosmag 4	183.50	27.31	160.42	62.18	12.01
Amofosmag 3	123.37	27.86	164.30	50.00	13.24
2009					
NPK	72.52	38.35	151.79	21.21	7.28
Amofosmag 4	80.09	42.95	131.39	23.34	8.29
Amofosmag 3	96.85	45.41	159.93	24.02	9.16
2019					
NPK	159.65	39.73	211.78	38.46	9.51
Amofosmag 4	179.73	43.67	199.40	41.61	10.42
Amofosmag 3	168.20	42.87	238.08	43.04	9.55

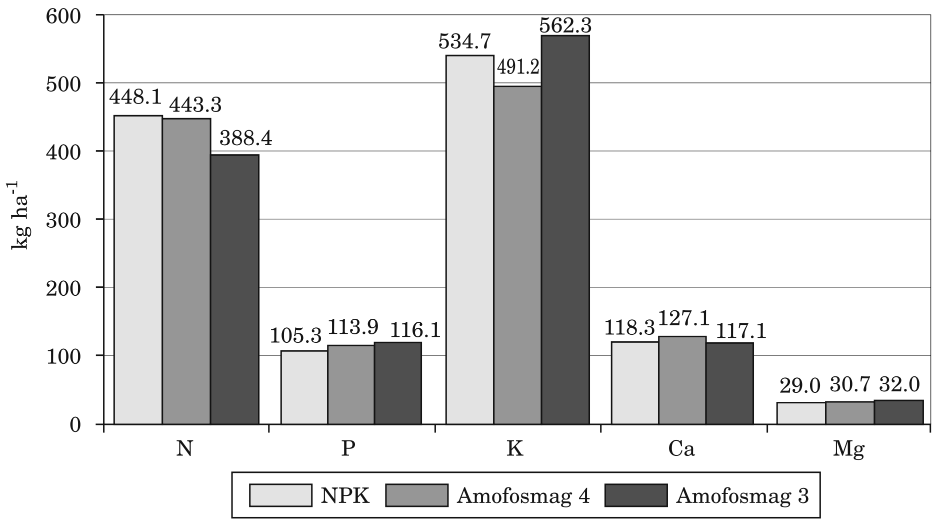

Fig. 1. Total macronutrient uptake by winter triticale over a three-year experimental period

Conclusions

1. The most beneficial effect was reported for Amofosmag 3 which increased the yield of winter triticale grain by 5% on average, compared with the control treatment.

2. The concentrations of the analyzed macronutrients in winter triticale grain and straw varied insignificantly between fertilization treatments. Simple and 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. The only exception was the nitrogen content of triticale grain which was highest in plots fertilized with simple fertilizers.

3. The highest total uptake of phosphorus, potassium and magnesium by winter triticale was noted in plots fertilized with Amofosmag 3, which may suggest that the nutrients contained in this product were more readily available to plants. Nitrogen uptake was higher in the control treatment, and calcium uptake in the Amofosmag 4 treatment.

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