J. Elem. s. 95–104 DOI: 10.5601/jelem.2012.17.1.09

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

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Abstract

Fertilization is the main factor and an indicator of the effectiveness of agricultural production. A wide variety and range of mineral fertilizers are currently available on the Polish market. They differ with respect to quality and price, while their names are often similar, which makes it difficult for the farmer to select the best one. There has been a steady increase in the share of multi-component fertilizers in total mineral fertilizer consumption in Poland, which seems very positive. Multi-component fertilizers supply a combination of nutrients at a time, in adequate amounts and proportions, in view of the content of available phosphorus, potassium and magnesium in the soil. The objective of this study was to determine the effect of mixed multi-component fertilizers on spring triticale 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: control treatment (simple fertilizers) and two treatments with mixed multi-component fertilizers, Amofosmag 4 (NPKMg 4:15:15:2) and Amofosmag 3 (NPKMg 3:14:20:2). The tested crop was spring triticale (*Triticosecale Wittm*) cv. Wanad. Amofosmag 4 had the most beneficial influence on the yield of spring triticale grain, which increased by 11% on average, compared with the control treatment. The effect of Amofosmag 3 was similar to that of simple fertilizers. Simple and multi-component fertilizers exerted a comparable effect on the mineral composition of triticale grain and straw, which remained within normal limits. More pronounced differences were observed in this respect between successive years of the study. The highest total uptake of nitrogen, phosphorus, potassium, calcium and magnesium by spring triticale was noted in plots fertilized with

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*This study was financed by Agrochem Ltd., Dobre Miasto.

Amofosmag 4, which indicates that the nutrients contained in this fertilizer are more readily available to plants compared with simple fertilizers and Amofosmag 3.

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

DZIAŁANIE NAWOZÓW WIELOSKŁADNIKOWYCH NA PLON, ZAWARTOŚĆ I POBRANIE MAKROELEMENTÓW PRZEZ PSZENŻYTO JARE

Abstrakt

Nawożenie jest podstawowym czynnikiem i zarazem wskaźnikiem efektywności produkcji rolniczej. Dostepny obecnie na polskim rynku bardzo szeroki i zróżnicowany pod względem jakościowym i cenowym asortyment nawozów mineralnych, o podobnych nazwach, często utrudnia rolnikowi wybór odpowiedniego nawozu. Pozytywnym zjawiskiem jest powolny, ale systematyczny wzrost udziału nawozów wieloskładnikowych w ogólnym zużyciu nawozów mineralnych przez polskiego rolnika. Nawozy wieloskładnikowe umożliwiają dostarczanie roślinom jednocześnie kilku składników pokarmowych w odpowiednich ilościach i proporcjach, najczęściej z uwzględnieniem zasobności gleby w przyswajalny fosfor, potas i magnez. Celem pracy była ocena wpływu zastosowanych nawozów wieloskładnikowych mieszanych na wielkość plonu, zawartość i pobranie makroelementów przez pszenżyto jare. Trzyletnie doświadczenie polowe (2005-2007) przeprowadzono w Zakładzie Dydaktyczno-Doświadczalnym w Tomaszkowie należącym do Uniwersytetu Warmińsko-Mazurskiego w Olsztynie. Doświadczenie, założone metodą losowanych bloków, obejmowało trzy obiekty nawozowe: obiekt kontrolny (nawozy jednoskładnikowe) oraz dwa nawozy wieloskładnikowe mieszane – Amofosmag 4 (NPKMg 4:15:15:2) i Amofosmag 3 (NPKMg 3:14:20:2). Rośliną testowaną było pszenżyto jare (*Triticosecale Wittm*) odmiany Wanad. Z badań wynika, że najkorzystniej na plon ziarna pszenżyta jarego wpłynął Amofosmag 4, który zwiększył go średnio o ok. 11% w porównaniu z obiektem kontrolnym. Natomiast Amofosmag 3 działał na poziomie nawozów jednoskładnikowych. Nawozy jednoskładnikowe i wieloskładnikowe podobnie kształtowały skład mineralny ziarna i słomy pszenżyta, który mieścił się w ogólnie przyjętych normach. Większe zróżnicowanie wystąpiło między poszczególnymi latami badań. Największe łączne pobranie azotu, fosforu, potasu, wapnia i magnezu przez pszenżyto jare stwierdzono po zastosowaniu Amofosmagu 4, co świadczy o lepszej przyswajalności składników pokarmowych z tego nawozu niż z nawozów jednoskładnikowych oraz z Amofosmagu 3.

Słowa kluczowe: pszenżyto jare, plon, makroelementy, nawozy wieloskładnikowe.

INTRODUCTION

A wide variety and range of multi-component fertilizers (solid, liquid and suspension) are currently available on the Polish market. They often have a similar composition, but are sold under different brand names, which makes it difficult for the farmer to select the best one. Fertilization rates should be adjusted to the requirements of the plant species, and should be determined in view of crop yield and quality, fertilizer efficiency and environmental issues. Compound fertilizers provide crops with essential nutrients in adequate amounts and proportions, and they help prevent or reduce nutrient leaching (CZUBA 1998, ZAWARTKA, SKWIERAWSKA 2004a). 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 counterbalance the progress of soil acidification, to correct magnesium deficiency in the soil and to reduce sulfur emissions, thus preventing nutrient deficiency in plants (FILIPEK 2001, NOWAK, DRASZAWKA-BOŁZAN 2001).

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

MATERIALS AND METHODS

In 2005-2007, a field experiment 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 (IV). The physicochemical properties of soil in each year of the study are presented in Table 1. The tested crop was spring triticale (*Tritico-secale Wittm*) cv. Wanad. The preceding plants were winter triticale in the first year, and winter rapeseed in the following two years. The plot surface area was 10 m˛.

Table 1

Selected physicochemical and chemical properties of the soil used in the experiment

Year	pH w 1 M KCl	Available forms (mg kg^{-1})		
		P	K	Mg
2005	6.15	56.70	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^{-1} Amofosmag 3 (NPKMg 3:14:20:2+22% CaO+9% SO_3; 9 kg N, 18 kg P and 50 kg K on pure ingredient basis) and Amofosmag 4 (NPKMg 4:15:15:2+24% CaO+9% SO_3; 12 kg N, 20 P and 37 kg K on pure ingredient basis) were applied pre-sowing. In the control treatment, the following fertilizers were applied pre-sowing: 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 K_2O (37 kg K) per ha in the form of potash salt. The nitrogen rate of 90 kg ha^{-1} was supplemented with two doses of ammonium nitrate applied by top-dressing, as follows: control treatment and Amofosmag 4 treatment – 50 and 28 kg N, Amofosmag 3 treatment – 50 and 31 kg N ha^{-1}.

Samples of spring triticale were collected at the stage of full maturity. The grain and straw harvested in each plot were 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). Total precipitation in April was substantially lower than the long-term average, which could have contributed to uneven emergence, whereas July was too wet. In 2006, the mean monthly temperatures were similar to the long-term average. The highest temperature was recorded in July. Precipitation levels differed considerably from the average values in July and August. Precipitation total in July and 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

Table 2

Weather conditions in 2005-2007 – data provided by the Meteorological Station in Tomaszkowo

Month	Mean daily temperature (°C)				Total precipitation (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
Mean	14.1	14.8	15.0	14.1	Σ249.1	Σ388.4	Σ448.0	Σ308.2

wet, with a difference of 99.9 mm between the mean monthly rainfall and the long period average. The weather conditions affected the yield of spring triticale.

The highest average yield of spring triticale grain (5.82 t ha^{-1}) was obtained in the first year of the study (Table 3). Amofosmag 4 contributed to a significant increment in grain yield, which was by 27% and 25% higher than in the control treatment (simple fertilizers) and in the Amofosmag 3 treatment, respectively. In another experiment, spring wheat also responded by yield increase to the application of Amofosmag 4 (NOGALSKA et al. 2010).

Table 3

Spring triticale yield after the application of Amofosmag 4 and Amofosmag 3 (t ha^{-1})

Treatment	Grain				Straw			
	2005	2006	2007	mean (*a*)	2005	2006	2007	mean (a)
NPK	5.31	4.25	3.81	4.46	5.70	7.05	5.15	5.97
Amofosmag 4	6.75	4.39	3.78	4.97	7.41	6.40	5.60	6.47
Amofosmag	5.39	4.02	3.73	4.38	6.29	6.33	5.14	5.92
Mean (*b*)	5.82	4.22	3.77		6.47	6.59	5.30	
$LSD_{p=0.05}$ for: *a*	0.29				n.s.			
b	0.33				0.54			
*a*x*b*	0.50				0.94			

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

In the second year of the study (2006), the yield of spring triticale grain ranged from 4.02 to 4.39 t ha^{-1}, depending on the applied fertilizer, and it was significantly lower (by 38% on average) than in the first year. Amofosmag 4 contributed to an approximately 10% increase in triticale grain yield, in comparison with Amofosmag 3. The lowest triticale grain yield was attained in 2007 – it was 35% and 11% lower than in 2005 and 2006, respectively. The above could have been due to the less favorable weather conditions. Triticale straw yield was less affected by the applied fertilizers. The highest straw yield, similarly as the highest grain yield, was obtained in the Amofosmag 4 treatment. Triticale straw yield was significantly lower (by over 1.2 tons) in the last year of the experiment than in the first and second year.

The means from the three years show that Amofosmag 4 caused an approximately 11% and 8% increase in the yield of triticale grain and straw, respectively, compared with the control treatment. The effect of Amofosmag 3 was similar to that of simple fertilizers. Other authors (MAZUR et al. 2001, STĘPIEŃ, MERCIK 2001, ZAWARTKA, SKWIERAWSKA 2004b) also observed a yieldforming effect of compound fertilizers in many plant species. On the other hand, KRZYWY et al. (2000) demonstrated that multi-component fertilizers had an insignificant effect on the yield of winter triticale and spring barley.

The results of chemical analyses of spring triticale grain and straw, presented in Table 4, suggest that the concentrations of the analyzed macronutrients varied insignificantly between fertilization treatments, and in most cases they remained within normal limits (*Norms for nutritions...* 2009). The grain of spring triticale fertilized with Amofosmag 3 had a significantly lower average nitrogen content, compared with the Amofosmag 4 and control treatments. The concentrations of phosphorus, potassium, calcium and magnesium were not significantly modified by the applied fertilizers. More pronounced differences were observed in this respect between successive years of the study. In the first year of the study (2005), the grain of spring triticale contained significantly less nitrogen and calcium and more magnesium, compared with the values noted in the two consecutive years. In the second year of the experiment, triticale grain contained larger amounts of nitrogen than in the first year, and significantly higher quantities of phosphorus and calcium and less potassium than in the first and third year. The highest average nitrogen content (23.0 g kg^{-1} d.m.) of triticale grain was observed in 2007, and it was significantly higher than in 2005 and 2006 (by 60% and 18%, respectively). The concentrations of the analyzed macronutrients in triticale straw varied between the years. The highest content of nitrogen was noted in the first year, of phosphorus and magnesium in the second year, and of potassium – in the third year. The findings of many other authors (KRZYWY et al. 2000, FILIPEK 2001, KRZYWY et al. 2001, MAZUR et al. 2001, NOGALSKA et al. 2010) suggest that multi-component fertilizers have an insignificant effect on the macronutrient content of tested plants.

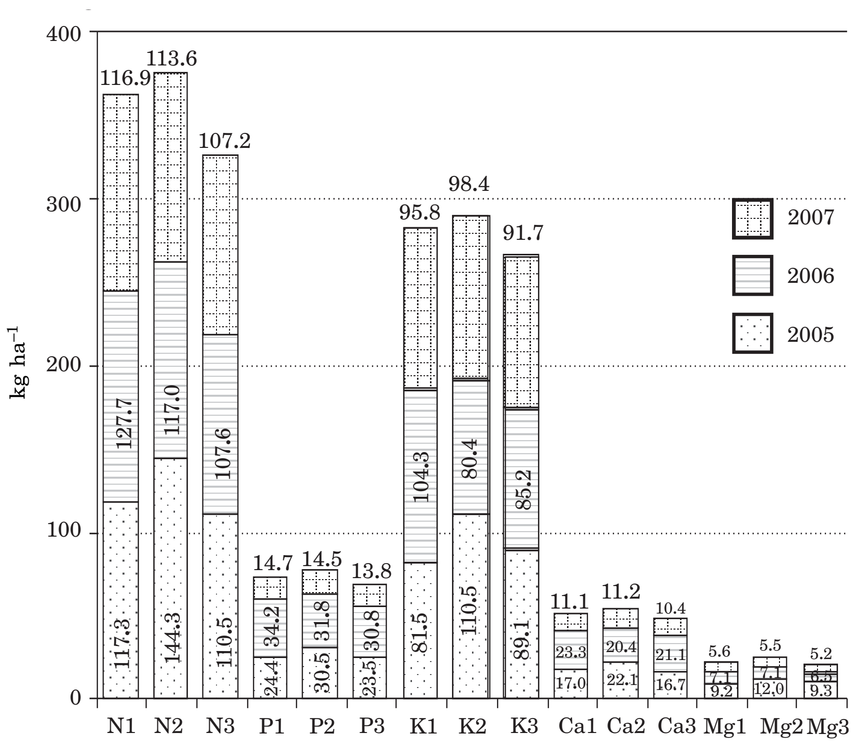
Macronutrient uptake was estimated based on the yield and macronutrient content of spring triticale grain and straw (Figure 1). The highest nitrogen uptake by spring triticale plants (144.3 kg N ha^{-1}) was noted in the first year of the experiment, following the application of Amofosmag 4, which resulted from the highest yield of triticale grain and straw in this treatment. Phosphorus uptake levels were comparable in all treatments. Phosphorus uptake varied between years – it was the highest in 2006 (32.3 kg P ha^{-1} on average) when triticale grain and straw were abundant in phosphorus, and nearly two-fold lower in the third year of the experiment. A similar trend was observed with regard to calcium uptake. Magnesium uptake decreased over time. The highest total (mean values of three years) uptake of the analyzed macronutrients (N, P, K, Ca and Mg) was noted in plots fertilized with Amofosmag 4. In the Amofosmag 3 treatment, macronutrient uptake was 7% lower than in the control treatment. This indicates that the nutrients contained in Amofosmag 4 are more readily available to spring triticale, in comparison with simple fertilizers and Amofosmag 3. STĘPIEŃ, MERCIK (2001), KRUCZEK, SULEWSKA (2005) and NOGALSKA et al. (2010) reported that multi-component fertilizers, compared with simple fertilizers, supported higher nutrient uptake by various plant species.

Table 4

Macronutrient content of spring triticale after the application of Amofosmag 4 and Amofosmag 3 (g kg^{-1} d.m.)

Macro-nutrient	Treatment	Grain				Straw			
		2005	2006	2007	mean (*a*)	2005	2006	2007	mean (*a*)
Nitrogen	NPK	14.9	20.1	23.8	19.6	6.65	6.04	5.07	5.92
	Amofosmag4	14.9	19.5	23.1	19.2	5.86	4.89	4.71	5.15
	Amofosmag3	13.5	18.9	22.0	18.1	5.97	4.99	4.90	5.29
Mean (*b*)		14.4	19.5	23.0	-	6.16	5.31	4.89	-
$LSD_{p=0.05}$ for:	*a* *b* *a*xb	0.89 0.90 n.s.				n.s. 0.62 n.s.			
Phosphorus	NPK	3.72	5.40	2.37	3.83	0.84	1.60	1.09	1.18
	Amofosmag4	3.62	5.25	2.37	3.75	0.84	1.40	0.97	1.07
	Amofosmag3	3.64	5.33	2.30	3.76	0.66	1.50	1.02	1.06
Mean (*b*)		3.66	5.32	2.35	-	0.78	1.50	1.03	-
$LSD_{p=0.05}$ for:	*a* *b* *a*xb	n.s. 0.15 n.s.				n.s. 0.14 n.s.			
Potassium	NPK	4.50	3.30	4.61	4.14	10.1	12.8	15.2	12.7
	Amofosmag4	4.30	3.05	4.37	3.91	11.0	10.5	14.6	12.0
	Amofosmag3	4.45	3.07	4.25	3.92	10.4	11.5	14.8	12.2
Mean (*b*)		4.42	3.14	4.41		10.5	11.6	14.9	-
$LSD_{p=0.05}$ for:	*a* *b* *a*xb	n.s. 0.21 n.s.				n.s. 1.49 n.s.			
Calcium	NPK	0.31	1.00	0.47	0.59	2.75	2.68	1.80	2.41
	Amofosmag4	0.31	1.01	0.44	0.59	2.75	2.54	1.75	2.35
	Amofosmag3	0.30	0.99	0.45	0.58	2.40	2.67	1.75	2.27
Mean (*b*)		0.31	1.00	0.45		2.63	2.63	1.77	-
$LSD_{p=0.05}$ for:	*a* *b* *a*xb	n.s. 0.061 n.s.				n.s. 0.28 n.s.			
Magnesium	NPK	1.43	0.99	1.02	1.15	0.29	0.41	0.34	0.35
	Amofosmag4	1.40	0.98	1.01	1.13	0.34	0.44	0.30	0.36
	Amofosmag3	1.42	0.99	0.95	1.12	0.26	0.40	0.32	0.33
Mean (*b*)		1.42	0.99	0.99	-	0.30	0.42	0.32	-
$LSD_{p=0.05}$ for:	*a* *b* *a*xb	n.s. 0.048 n.s.				n.s. 0.037 n.s.			

Explanations as in Table 3



1 – NPK, 2 – Amofosmag 4, 3 – Amofosmag 3

Fig. 1. Nutrient uptake by spring triticale grain and straw in 2005-2007 (kg ha^{-1})

CONCLUSIONS

1. Amofosmag 4 contributed to an approximately 11% and 8% increase in the yield of spring triticale grain and straw, respectively, compared with the control treatment. The effect of Amofosmag 3 was similar to that of simple fertilizers. Triticale grain yield was significantly higher in the first year of the study than in the second and third year.

2. The concentrations of the analyzed macronutrients in spring triticale grain and straw varied insignificantly between fertilization treatments. In most cases, simple and multi-component fertilizers exerted a comparable effect on the chemical composition of the tested crop. Significant differences were observed in this respect between successive years of the study.

3. The highest total uptake of N, P, K, Ca and Mg by spring triticale was noted in plots fertilized with Amofosmag 4. Macronutrient uptake from Amofosmag 3 was lower than from simple fertilizers.

REFERENCES

CZUBA R. 1998. *Optymalny asortyment podstawowych nawozów wieloskładnikowych warunkowany krajową strukturą zasiewów i zasobnością gleb [The optimum range of multi-component fertilizers conditioned by the structure of crops and soil mineral abundance in Poland].* Fol. Univ. Agric. Stetin. Agricultura, 190 (72): 43-48. (in Polish)

KRUCZEK A., SULEWSKA H. 2005. *Wpływ sposobu stosowania nawozów azotowych i nawozu wieloskładnikowego na gromadzenie składników mineralnych w początkowym okresie wzrostu kukurydzy [Effect of the way nitrogen fertilizers and multi-component fertilizer are applied on accumulation of nutrients in the early development of maize].* Acta Agroph., 6(3): 677-688. (in Polish)

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 [Effect of multi- and single-component fertilizers on the yield volume and some yield quality parameters of crops.* Part I. *Effect of multi- and single-component fertilizers on the yield volume and some yield quality parameters of crops and their content of nitrogen, phosphorus, calcium, magnesium and sulphur.* Fol. Univ. Agric. Stetin. Agricultura, 223 (89): 99-106. (in Polish)

KRZYWY E., JAKUBOWSKI W., PASIKOWSKI J. 2000. *Wpływ nawozów wieloskładnikowych i jednoskładnikowych na wysokość plonów i niektóre cechy jakościowe pszenżyta ozimego i jęczmienia jarego [Effect of multi-component and simple fertilizers on yield volume and some yield quality parameters of winter triticale and sprng barley].* Fol. Univ. Agric. Stetin. Agricultura, 204 (81): 163-168. (in Polish)

FILIPEK T. 2001. *Zawartość składników pokarmowych a zastosowanie nawozów wieloskładnikowych z KIZPS "Siarkopol" [Concentration of nutrients versus application of multi-component fertilizers from the KIZPS Siarkopol].* Fol. Univ. Agric. Stetin. Agricultura, 223 (89): 41-46. (in Polish)

MAZUR T., MAZUR Z., WOJTAS A., GRZEŚKOWIAK A. 2001. *Wpływ nawozów wieloskładnikowych na wielkość i jakość plonów roślin uprawianych w 4-polowym zmianowaniu [Effect of multi-component fertilizers on volume and quality of yield of crops grown in 4-field rotation].* Fol. Univ. Agric. Stetin. Agricultura, 223 (89): 113-120. (in Polish)

NOGALSKA A., CZAPLA J. SKWIERAWSKA M. 2010. *The effect of multi-component fertilizers on spring wheat yield, the content and uptake of macronutrients*. Pol. J. Natur. Sc., 25(4): 323-331.

NOWAK W., DRASZAWKA-BOŁZAN B. 2001. *Zawartość makroelementów w życicy trwałej pod wpływem stosowania nawozów wieloskładnikowych [Concentration of macronutrients in perennial ryegrass under the influence of multi-component fertilizers].* Biul. Magnezol., 6(3): 310-315. (in Polish)

STĘPIEŃ W., MERCIK S. 2001. *Działanie na rośliny i glebę nawozów wieloskładnikowych i pojedynczych w zmianowaniu pięciopolowym [The impact of mulit-component and simple fertilizers on crops and soil in five-feld rotation].* Fol. Univ. Agric. Stetin. Agricultura, 223 (89): 165-168. (in Polish)

Normy żywienia przeżuwaczy 2009. Wartość pokarmowa francuskich i krajowych pasz dla przeżuwaczy. [Norms for Nutrition of Ruminants. Nutritive value of French and Polish feeds for ruminants]. Ed. J. STRZETELSKI. Inst. Zootech. PIB, Kraków. (in Polish)

ZAWARTKA L., SKWIERAWSKA M. 2004a. *Wpływ nawozów wieloskładnikowych na wymywanie fosforu i innych makroelementów z gleby [Effect of multi-component fertilizers on the leaching of phosphorus from soil].* Pr. Nauk. AE Wrocław, Chemia, 1017: 69-77. (in Polish)

Zawartka L., Skwierawska M. 2004b. *Wpływ nawozów wieloskładnikowych na plon i zawartość fosforu i innych makroelementów w jęczmieniu jarym [Effect of multi-component fertilizers on yield and content of pphosphorus and other macronutrients in spring barley]*. Pr. Nauk. AE Wrocław, Chemia, 1017: 149-157. (in Polish)