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THE EFFECT OF NITROGEN FERTILIZERS ON CHEMICAL COMPOSITION OF SPRING TRITICALE GRAIN

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Abstract. The aim of the research based on the results of a field experiment was comparison of the effect of two nitrogen fertilizers: the traditional ammonium nitrate and SULFAMMO 30 N PRO. The analysis comprises the effect of the aforementioned fertilizers on the chemical composition of triticale grain (*xTriticosecale* Wittm. ex A. Camus), cv. Nagano. The field experiment was carried out in the years 2013-2014 at the Experimental Agricultural Station in Lipnik (53º42′ N; 14º97′ S). The modern fertilizer SULFAMMO 30 N PRO contains 30% N (in the most effective forms: ammonium and amide), 15% SO_3 3% MgO. There were no significant differences between the analyzed fertilizers (ammonium nitrate and SULFAMMO 30 N PRO) in terms of the content of the analysed macro- and microelements: nitrogen, phosphorus, potassium, calcium, magnesium, iron, zinc and copper in the grain of spring triticale, cv. Nagano. Application of nitrogen fertilization at the highest dose of 120 kg $N \cdot ha^{-1}$ resulted in a significant increase in nitrogen and iron content in the spring triticale grain. On the whole, the results of the experiment indicate high stability in terms of macro- and microelements content in spring triticale grain of Nagano cultivar.

Key words: macroelement, microelement, Nagano cultivar, nitrogen fertilization, *Triticosecale*

INTRODUCTION

Triticale (*Triticosecale*) is a synthetic, intergeneric hybrid of wheat and rye which combines features of the species used for crossing. Wheat and rye were crossed for the first time in Edinburgh in 1875 by Willson, however the plants were sterile. The first

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stable and fertile hybrids were produced in 1889 by a German farmer Rimpau who developed alloploid hybrids with 56 chromosomes in somatic cells by crossing common wheat with common rye [Ammar *et al.* 2004]. Spring triticale (*xTriticosecale* Wittm. ex A. Camus) cv. Nagano, was developed in Poland by DANKO Hodowla Roślin Ltd. in Chorynia and was included in the National List of Varieties in 2008 [Gacek 2014]. It is an early cultivar of an average protein content, it is characterized by a relatively good fertility on the entire area of Poland, and is typically used as feed [Najewski *et al.* 2009]. The grain of Nagano cultivar is course, characterized by high uniformity and minor share of screenings. In fact, except for yield loss and seeding material, the whole grain weight is used as feed. Triticale of Nagano cultivar was one of the three cultivars recommended for farming in West Pomeranian Voivodeship in 2013 [Najewski 2013].

Many authors undertake detailed analysis of the grain in terms of the content of total protein, starch and ash [Gil 2001, Stacey *et al.* 2006, Burešová *et al.* 2010, Lestingi *et al.* 2010, Kowieska *et al.* 2011, Bona *et al.* 2014]. However, due to the nutritional value of spring triticale grains, it is necessary to carry out an analysis of the grain composition in terms of changes in macro- and microelements. Chemical composition of the grain, and at the same time its fodder value, depends on various factors, notably on the applied fertilization – particularly with nitrogen.

Producers of nitrogen fertilizers aim at developing increasingly modern products which contain nutrients most available for plants. One such type of fertilizers is N PRO nitrogen complex fertilizer which can be used in agriculture and horticulture. The technology applied in developing this type of fertilizer is a combination of the most effective forms of nitrogen (ammonium and amide), sulphur, magnesium and Mezocalc with N-PRO complex increasing the efficacy of nitrogen metabolism in a plant. SULFAMMO 30 N PRO is a modern fertilizer which contains: 30% N, 15% SO_3 3% MgO, N-PRO – produced by TIMAC Agro Polska company. SULFAMMO 30 N-PRO fertilizer does not contain nitrates and, because of N-PRO content, it facilitates quicker assimilation and conversion of nitrogen into protein. Moreover, thanks to a proper content of assimilable sulphur and magnesium, it helps in nitrogen metabolism. Addition of calcium (Mezocalc) results in neutralization of soil acidity [www.timcargo.pl].

The aim of the study based on the results of the field experiment was comparison of the effect of two nitrogen fertilizers: traditional ammonium nitrate and SULFAMMO 30 N PRO. The analysis comprises the effect of using the aforementioned fertilizers on chemical composition of triticale, cv. Nagano. Various doses were applied, and the grain was analyzed in terms of the content of: nitrogen, phosphorus, potassium, calcium, magnesium, iron, zinc, copper and cadmium.

MATERIAL AND METHODS

The field experiment was carried out in the years 2013-2014 at the Experimental Agricultural Station in Lipnik (53º42′ N; 14º97′ S), property of West Pomeranian Technological University in Szczecin. The experiment was set on light, good rye complex soil of the IVa soil class. The soil is classified as brown soil developed from light loamy sands, and has a slightly acidic pH (pH in 1mol KCl – 6.5). In the experimental soil the content of average exchangeable potassium was 108.0 mg $K \cdot kg^{-1}$ and exchangeable phosphorus 56.0 mg $P \cdot kg^{-1}$. The material for the analysis consisted of samples of spring triticale (*xTriticosecale* Wittm. ex A. Camus), cv. Nagano. The experiment was conducted by means of a split-plot design with four replications. The analyzed factors were: two types of nitrogen fertilizers – ammonium nitrate and SULFAMMO 30 N PRO (factor 1), and four doses of nitrogen fertilization: 0, 40, 80, and 120 kg per hectare (factor 2). Cultivation was performed according to the generally accepted agrotechnical recommendations. Nitrogen fertilizer was distributed before sowing (40 kg $N \cdot ha^{-1}$), at the shooting stage (40 kg $N \cdot ha^{-1}$), and at earing stage depending on the applied dose. Fertilization in the amount of 50 kg $P \cdot ha^{-1}$ and 80 kg $K \cdot ha^{-1}$ was performed in whole before sowing. The grain was sown in the last week of March in the amount of 450 germinating seeds per square meter. Harvesting was done with the use of a plot harvester – in both years the time of harvest was the first week of August. The analysis was performed on the mean replication samples of grain for all experimental combinations.

The grain was analyzed as for the total content of macroelements, i.e. nitrogen, potassium, calcium, magnesium, and microelements, i.e. iron, zinc, cadmium. Nitrogen was determined in the solutions derived from mineralization of the seed samples in sulphuric acid(VI) with H_2O_2 – Kjeldahl's method. Total elements (K, Ca, Mg, Fe, Mn, Zn, Pb, Cd, Ni and Cu) were determined in the seeds after wet burning in a mixture of nitric(V) and chloric(VII) acids. The analyses were conducted using an Absorption Spectrometer apparatus (Thermo Fisher Scientific ICE 3000 Series). Phosphorus was colorimetrically determined with ammonium molybdate at a wavelength of 470 nm.

The results were statistically analyzed with the use of the analysis of variance of a completely randomized design, with consecutive years of the experiment taken as replications. Tukey's confidence half-intervals were calculated at the level $p = 0.05$. The statistical analysis of the results was conducted using Statistical 10 software.

The mean temperature recorded in the growing season in 2013 and 2014 was similar to the mean from the period 1980-2009. The amount of precipitation in March, April, June and July 2013 was much lower than that recorded in the long-term period, thus allowing for assessing the growing season as dry (36.8% of the mean value). In April, May, June and July 2014, the amount of rainfall was higher than that recorded for the long-term period – the growing season can be classified as humid (123.7% of the mean value), (Table 1).

Table 1. Average monthly temperature and total rainfall during spring growing season at the Agricultural Experimental Station in Lipnik compared to a long-term period 1980-2009
Tabela 1. Średnie miesięczne temperatury i opady deszczu w czasie okresu wegetacyjnego w Rolniczej Stacji Doświadczelnej w Lipniku w porównaniu z okresem wieloletnim 1980-2009

Month – Miesiąc	Temperature – Temperatura, °C			Rainfall – Opady, mm		
	2013	2014	1980-2009	2013	2014	1980-2009
March – Marzec	-1.7	5.8	3.9	6.9	37.6	39.6
April – kwiecień	7.7	9.8	8.3	23.2	51.3	34.1
May – Maj	14.2	12.4	13.6	42.5	60,9	47.7
June – Czerwiec	16.5	15.8	16.2	14.4	82.8	65.3
July – Lipiec	19.2	20.7	18.5	4.7	66.6	62.4
Mean/total – Średnia/suma	11.2	12.9	12.1	91.7	299.2	249.1

RESULTS AND DISCUSSION

The intensity of dry matter accumulation and the final triticale grain yield are determined to a large extent by nitrogen and water accessibility. The yield-forming property of nitrogen is connected with chlorophyll synthesis and intensity of photosynthesis processes, as well as an increase in the production of protein – nitrogen being its main constituent. Triticale grain is characterized by a variable content of nitrogen. The results of the experiment with spring triticale, cv. Milewo, carried out by Wysokiński *et al.* [2014] show that the mean content of nitrogen in grain was 20.24 g $N \cdot kg^{-1}$ d.m. According to the research on the effect of growth regulator on mineral metabolism of spring triticale, cv. Migo, conducted by Wierzbowska *et al.* [2010], the mean nitrogen content in grain was 24,80 g $N \cdot kg^{-1}$ d.m. The nitrogen content in the grain of triticale cv. Nagano used in the experiment was 17.09 g $N \cdot kg^{-1}$ d.m. (Table 2). The comparison of mean values for the two-year period shows that the type of fertilization applied did not have any effect on the content of nitrogen in the grain. However, application of nitrogen fertilization at a dose of 120 kg N per hectare resulted in a significant increase in the nitrogen content in grain to as much as 17 g $N \cdot kg^{-1}$ d.m. The relationship between the increase in the nitrogen content and protein linked to it, is in line with numerous studies on this subject by: Alaru *et al.* [2003], Oracka and Łapiński [2006], Lestingi *et al.* [2010], Janušauskaitė [2013], Wysokiński *et al.* [2014]. According to the results of applying various doses of nitrogen obtained by Wojtkowiak [2014], the most effective in terms of an increase in the protein yield in spring triticale grain, cv. Milewo, was fertilization in the amount of 120 kg $N \cdot ha^{-1}$, and the increase in protein yield was determined by nitrogen content.

Table 2. Macroelements content in triticale grain depending on the kind of fertilizer (F), and nitrogen dose (D)
Tabela 2. Zawartość makroskładników w ziarnie pszenżyta w zależności od rodzaju nawozu (F) oraz dawki azotu (D)

Fertilization Nawożenie (F)	Dose (D) Dawka kg $N \cdot ha^{-1}$	Nitrogen Azot g $N \cdot kg^{-1}$ d.m.	Phosphorus Fosfor g $P \cdot kg^{-1}$ d.m.	Potassium Potas g $K \cdot kg^{-1}$ d.m.	Calcium Wapń mg $Ca \cdot kg^{-1}$ d.m.	Magnesium Magnez mg $Mg \cdot kg^{-1}$ d.m.
SULFAMMO 30 N-PRO	0	15.84	3,85	5.09	157.5	1105.7
	40	16.56	4,42	5.16	181.6	1094.8
	80	16.40	3.28	5.17	188.7	1054.1
	120	19.36	2.80	5.31	156.8	1098.8
Mean – Średnia		17.04	3.59	5.18	171.1	1088.4
Ammonium nitrate Azotan amonowy	0	15.55	4.85	5.38	187.4	1177.3
	40	15.39	3.65	5.12	168.6	1128.9
	80	17.30	4.15	5.39	181.8	1090.5
	120	20.29	4.08	5.38	182.4	1097.5
Mean – Średnia		17.13	4.18	5.32	180.0	1123.6
Mean Średnia	0	15.70	4.34	5.24	172.4	1141.5
	40	15.98	4.03	5.14	175.1	1111.9
	80	16.85	3.72	5.28	169.6	1072.3
	120	19.83	3.44	5.35	171.1	1098.2
Total mean		17.09	3.88	5.25	172.0	1106.0
$LSD_{0.05}$ – $LSD_{0,05}$ for – dla:		F ns – ni D 3.518 F × D ns – ni	F ns – ni D ns – ni F × D ns – ni	F ns – ni D ns – ni F × D ns – ni	F ns – ni D ns – ni F × D ns – ni	F ns – ni D ns – ni F × D ns – ni

ns – ni – non-significant differences – różnice nieistotne

Proper nutrition with phosphorus and potassium plays a significant role in ensuring that the triticale yield is close to the potential yield. These elements play a crucial role in physiological processes of plants and take part in photosynthesis process, assimilation and protein synthesis [Marschner 1995]. However, the role of potassium in triticale yield is unlike that of phosphorus. Proper nutrition with phosphorus is the condition of the effective plant water management. The yield-forming effect of potassium is connected with an increased production of protein and sugar. The amount of phosphorus and potassium in spring triticale grain generally ranges from 3 to 5 $g \cdot kg^{-1}$ d.m. – such content was also found in triticale cv. Nagano (Table 2). The results which were analyzed statistically with the use of the analysis of variance of a completely randomized design, do not show any significant influence of the dosage and types of nitrogen fertilizer on changes in phosphorus and potassium content in spring triticale grain cv. Nagano (Table 2).

The total calcium content in spring triticale grain, cv. Nagano, was 172 $mg\ Ca \cdot kg^{-1}$ d.m. The applied fertilizers did not have any significant effect on the content of calcium in the grain. The content of calcium in triticale grain remained at a stable level.

The results do not show any effects of nitrogen fertilizers used in the course of the experiment on the magnesium content in spring triticale grain of Nagano cultivar. The content of magnesium in triticale grain was at the level of 1106.0 $mg \cdot kg^{-1}$ d.m. (Table 2).

Similar dependence of high stability of chemical composition and the content of phosphorus, potassium, calcium and magnesium can be found in other studies, i.e. by Wierzbowska *et al.* [2010], Nogalska *et al.* [2012], Wojtkowiak [2014].

The use of nitrogen fertilizers (SULFAMMO 30 N PRO and ammonium nitrate) had a similar effect on the mineral content in triticale grain, cv. Nagano, which was within the generally accepted norms [Norms for Nutrition of Ruminants 2009].

Microelements are mainly catalysts of physiological processes in plants. Iron in plants is found at the second and third oxidation level, and both cations (Fe^{3+} and Fe^{2+}) act as catalysts in many reactions related to protein synthesis, nucleic acid metabolism in particular. Grains of other cereals are characterized by a similar content of iron, that is from 17 to 50 $mg\ Fe \cdot kg^{-1}$ [Kabata-Pendias 2011].

The content of iron in triticale grain of Nagano cultivar used in the experiment was within the range of 14.38-22.88 $mg\ Fe \cdot kg^{-1}$ d.m. The results of the statistical analysis with the use of the analysis of variance of a completely randomized design, do not reveal any significant effect of the type of fertilizer used on variation in the iron content of spring triticale grain, cv. Nagano. However, application of a nitrogen fertilizer in the amount of 120 kg N per hectare resulted in an increase in iron content in grain to the level of 23 $g\ Fe \cdot kg^{-1}$ d.m. (Table 3). A similar effect is reported by Wojtkowiak *et al.* [2014], namely that nitrogen fertilization in the amount of 120 $kg \cdot ha^{-1}$ together with Azofoska and Ekolist brought an increase in the iron content in the grain of Andrus cultivar. This may be explained by the fact that this element, to a very large extent, participates in protein metabolism, and fertilization with nitrogen has the strongest effect on protein metabolism in a plant.

The basic functions of zinc in a plant are connected with carbohydrates, proteins and phosphate [Lindsay 1972]. According to Kabata-Pendias [2011], the mean content of zinc in wheat and barley grains was 24 and 26 $mg\ Zn \cdot kg^{-1}$, respectively. The results of the present analysis show a similar content of zinc in triticale, that is approximately 23.4 $mg\ Zn \cdot kg^{-1}$ (Table 3).

Table 3. Microelements content in triticale grain depending on the kind of fertilizer (F), and nitrogen dose (D)

Table 3. Zawartość mikroskładników w ziarnie pszenżyta w zależności of rodzaju nawozu (F) oraz dawki azotu (D)

Fertilization – Nawożenie (F)	Dose – Dawka kg $N \cdot ha^{-1}$ (D)	Iron – Żelazo mg $Fe \cdot kg^{-1}$ d.m.	Zinc – Cynk mg $Zn \cdot kg^{-1}$ d.m.	Copper – Miedź mg $Cu \cdot kg^{-1}$ d.m.
SULFAMMO 30 N PRO	0	14.38	21.82	2.70
	40	16.99	23.14	2.83
	80	15.63	21.88	2.24
	120	22.88	24.64	2.56
Mean – Średnia		17.47	22.87	2.58
Ammonium nitrate Azotan amonowy	0	14.66	23.79	3.05
	40	16.26	23.08	2.74
	80	18.57	24.23	2.63
	120	19.95	24.47	2.44
Mean – Średnia		17.36	23.89	2.72
Mean – Średnia	0	14.52	22.81	2.88
	40	16.63	23.11	2.79
	80	17.10	23.05	2.44
	120	21.42	24.56	2.50
Total mean		17.42	23.38	2.65
$LSD_{0.05}$ – $LSD_{0,05}$ for – dla:		F ns – ni D 4.903 F × D ns – ni	F ns – ni D ns – ni F × D ns – ni	F ns – ni D ns – ni F × D ns – ni

Copper is a relatively immobile element in plants. The relationship between copper and zinc is widely recognized in literature on the subject. Metals are absorbed according to the same mechanism, and can mutually inhibit absorption via the root system [Graham 1981]. The results of the analysis show that the copper content in triticale grain ranged from 2.24 to 3.05 mg $Cu \cdot kg^{-1}$ – the value being approximately ten times lower than that regarding zinc.

The statistical analysis of the results of the experiment performed with the analysis of variance of a completely randomized design, does not show any significant effect of dosage and type of nitrogen fertilization on changes in the zinc and copper content in spring triticale, cv. Nagano (Table 3).

Cadmium and lead are toxic elements and their maximum content in animal feeds is regulated by the Commission Regulation (EU) No 1275/2013. The limit value of lead content is 10 mg $Pb \cdot kg^{-1}$ d.m., and for cadmium 1 mg $Cd \cdot kg^{-1}$ [Commission Regulation (EU) No 1275/2013 7.12.2013 L 328/86]. Spring triticale grain, cv. Nagano, fertilized with both ammonium nitrate and SULFAMMO 30 N PRO applied at various doses did not contain lead or cadmium.

CONCLUSIONS

1. There were no significant differences between the analyzed fertilizers (ammonium nitrate and SULFAMMO 30 N PRO), in terms of the content of the analysed macroelements: nitrogen, phosphorus, potassium, calcium and magnesium in the grain of spring triticale, cv. Nagano.

2. Application of nitrogen fertilization at the highest dose (120 kg N·ha^{-1}) resulted in a significant increase in the content of nitrogen and iron in spring triticale grain of Nagano cultivar.

3. The statistical analysis of the results does not show any significant effect of nitrogen dosage and type of fertilizers (ammonium nitrate and SULFAMMO 30 N PRO) on changes in the content of zinc and copper in spring triticale grain.

4. On the whole, the results of the experiment indicate high stability in terms of macro- and microelements content in spring triticale grain of Nagano cultivar.

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www.timcargo.pl.

WPŁYW NAWOZÓW AZOTOWYCH NA SKŁAD CHEMICZNY ZIARNA PSZENŻYTA JAREGO

Streszczenie. Celem badań opartych na wynikach doświadczenia polowego było porównanie działania dwóch nawozów azotowych tradycyjnego, czyli saletry amonowej i SULFAMO 30 N Pro. Analizie poddano wpływ tych nawozów na skład chemiczny ziarna pszenżyta odmiany Nagano. Doświadczenie polowe przeprowadzono w latach 2013-2014 w Rolniczym Zakładzie Doświadczalnym w Lipniku (53º42' N; 14º97' S). Materiał do analizy stanowiło ziarno pszenżyta jarego (*xTriticosecale* Wittm. A. Camus ex), odmiany Nagano. Nawożenie zarówno saletrą amonową, jak i SULFAMO 30 N Pro nie spowodowało zmian zawartości w ziarnie pszenżyta jarego odmiany Nagano analizowanych makro- i mikroskładników, tj. azotu, fosforu, potasu, wapnia, magnezu, cynku i miedzi. Zastosowanie nawożenia azotowego w najwyższej dawce (120 kg $N \cdot ha^{-1}$) wpłynęło na istotny wzrost zawartości azotu i żelaza w ziarnie pszenżyta jarego. Podsumowując wyniki uzyskane w doświadczeniu, należy podkreślić dużą stabilność odnośnie zawartości makro- i mikroskładników w ziarnie pszenżyta jarego odmiany Nagano.

Słowa kluczowe: makroskładniki, mikroskładniki, nawożenie azotowe, odmiana Nagano, *Triticosecale*

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