POLISH JOURNAL OF NATURAL SCIENCES
Abbrev.: Pol. J. Natur. Sc., Vol 30(2): 173–184, Y. 2015

EFFECT OF NITROGEN FERTILIZATION METHOD ON THE YIELD AND QUALITY OF MILEWO VARIETY SPRING TRITICALE GRAIN

***Katarzyna Wojtkowiak*[1], *Arkadiusz Stępień*[2], *Małgorzata Warechowska*[1] *Agnieszka Markowska*[1]**

[1] Department of Fundamentals of Salety,
[2] Department of Agroecosystems
University of Warmia and Mazury in Olsztyn

K e y w o r d s: nitrogen fertilization, grain and protein yield, nutrients.

A b s t r a c t

In this paper the effect of soil fetilization (NH_4NO_3 and $CO(NH_2)_2$) foliar fertilization ($CO(NH_2)_2$) with and without Ekolistem on selected grain quality parameters and the yield of Milewo variety spring triticale was determined. It was found based on the obtained results that the nitrogen fertilization level and the years of research affected the grain, protein yield and the concentrations of (selected) minerals in spring triticale grain. The highest grain and protein yield of Milewo variety spring triticale was obtained after the application of nitrogen fertilization at the rate of 120 kg ha^{-1}. Protein yield increased with the increasing grain yield and the coefficient of determination was close to the linear correlation coefficient (R^2 = 0.936). The applied nitrogen fertilization 120 kg ha^{-1} affected grain phosphorus content. Lack of basic mineral fertilization (120 kg N ha^{-1}) supplementation with the mixed fertilizer with additional micronutrients resulted in an increase in grain potassium content. Joint application of urea plus Ekolist with 80 kg N ha^{-1} caused an increased amount of magnesium compared to the higher fertilization level.

WPŁYW SPOSOBU NAWOŻENIA AZOTEM NA PLONOWANIE I JAKOŚĆ ZIARNA PSZENŻYTA JAREGO ODMIANY MILEWO

Katarzyna Wojtkowiak[1], ***Arkadiusz Stępień*[2], *Małgorzata Warechowska*[1] *Agnieszka Markowska*[1]**

[1] Katedra Podstaw Bezpieczeństwa,
[2] Katedra Agroekosystemów
Uniwersytet Warmińsko-Mazurski w Olsztynie

S ł o w a k l u c z o w e: nawożenie azotem, plon ziarna i białka, składniki pokarmowe.

Address: Katarzyna Wojtkowiak, University of Warmia and Mazury, ul. Heweliusza 10, 10-719 Olsztyn, Poland, phone: +48 (89) 524 56 14, e-mail: katarzyna.wojtkowiak@uwm.edu.pl

Abstrakt

Celem pracy było określenie wpływu zróżnicowanego nawożenia doglebowo (NH_4NO_3 and $CO(NH_2)_2$) oraz dolistnie ($CO(NH_2)_2$) bez i z Ekolistem na wybrane parametry jakościowe ziarna i plonowanie pszenżyta jarego odmiany Milewo. Na podstawie uzyskanych wyników stwierdzono, że poziom nawożenia azotem i lata badań wpływały na plon ziarna, białka i koncentracje (wybranych) składników mineralnych w ziarnie pszenżyta jarego. Najwyższy plon ziarna i białka pszenżyta jarego odmiany Milewo uzyskano po zastosowaniu nawożenia azotem w dawce 120 kg ha^{-1}. Wraz ze wzrostem plonu ziarna wzrastał plon białka, a współczynnik determinacji był bliski współczynnikowi korelacji liniowej (R^2=0,936). Nawożenie azotem w dawce 120 kg ha^{-1} wpłynęło na zawartość fosforu w ziarnie. Brak uzupełnienia podstawowego nawożenia mineralnego (120 kg N ha^{-1}) nawozem wieloskładnikowym z dodatkiem mikroelementów zwiększało zawartość potasu w ziarnie. Łączne stosowanie mocznika i Ekolistu w dawce 80 kg N ha^{-1} w porównaniu z wyższym poziomem nawożenia spowodowało wzrost ilości magnezu.

Introduction

Modern plant production technology aimed at obtaining a high grain yield of proper quality should include balanced fertilization with all necessary nutrients (KOCOŃ 2009).

In intensive agricultural production, the fertilization level and the time of application is the decisive measure in achieving a high crop output with good quality properties (KNAPOWSKI et al. 2009, JANUŠAUSKAITĖ 2013, WARECHOWSKA et al. 2013). Nitrogen is undoubtedly the key factor determining cereal yield to the greatest degree. This nutrient modifies both the yield of its chemical composition and the grain feed value (WRÓBEL 2005, KNAPOWSKI et al. 2010). An important element of crop cultivation technology is foliar nitrogen fertilization combined with mixed fertilizers containing a set of properly selected micronutrients (DOMSKA et al. 2009, WOJTKOWIAK et al. 2014). This fertilization method enables the quick provision of minerals in short supply for the plants, both if they are deficient in soil and if the uptake is difficult. These nutrients are responsible for the synthesis and metabolism of many compounds and thus affect the quality of the obtained yield and the possibilities of its use in human and animal nutrition. Research by MALAKOUTI (2008) shows that the application of combined mineral and micronutrient fertilization increases grain yield and also improves the nutritional value of cereal grain.

Spring triticale cultivation is becoming increasingly important, especially in areas with unfavourable conditions in winter. According to SANTIVERI et al. (2002), spring triticale grain is characterized by a higher grain yield (from 896 to 1758 kg ha^{-1}) than the winter form of triticale. According to ROYO and PARES (1996) winter triticale yielded about 43% more forage than spring types, but after forage removal the spring types yielded about 36% more grain than winter triticale. The area under triticale in the world amounts to 3.7 million ha, with 1/3 in Poland (FAO 2013), but this is mainly winter cultivation. Compared to winter triticale, the number of varieties is small, yet they differ considerably in terms of many agricultural and quality traits. Nine spring triticale varieties are currently registered in the national variety register (COBORU 2013). The Milewo variety was developed in the Strzelce Breeding Center (IHAR group) and entered in the register in 2008. It is the highest yielding spring triticale variety in Poland in the years 2011 and 2012.

In this paper the effect of soil fetilization (NH_4NO_3 and $CO(NH_2)_2$) foliar fertilization ($CO(NH_2)_2$) with and without Ekolistem on selected grain quality parameters and the yield of Milewo variety spring triticale was determined.

Materials and Methods

A field experiment was conducted in the years 2010-2011 at the Didactic and Experimental Station in Tomaszkowo belonging to the University of Warmia and Mazury in Olsztyn (53°72'N; 20°42'E). The experiment was carried out using the random block method in triplicate on surface brown soil with the granulometric composition of light loam classified as Haplic Cambisol according to FAO-WRB (2006). The soil was characterized by an average abundance of phosphorus, potassium, zinc and manganese and a low abundance of copper and a slightly acid reaction (Table 1).

Table 1

Soil properties (average 2010–2011)

Parameter, unit		Value
Type of soil (FAO-WRB 2006)		Haplic Cambisol
pH in KCl		5.05
$C_{org.}$ [g kg^{-1}]		7.71
$N_{tot.}$ [g kg^{-1}]		0.97
Content of mineral [mg kg^{-1}]	P	108.8
	K	207.5
	Mg	50.0
	Zn	14.5
	Mn	182.0
	Cu	2.10

Triple superphosphate at a rate corresponding to 30.2 kg P ha^{-1} was used for fertilization to enrich the soil with phosphorus, and potassium was applied in the form of 56% potash salt at a rate equal to 83.1 kg K.

The factor differentiating the fertilized objects was the nitrogen rate and application method and the fertilizer form (Table 2). Nitrogen fertilization was applied in the amount of 80 and 120 kg N ha^{-1}. For soil fertilization ammonium nitrate (NH_4NO_3) and urea ($CO(NH_2)_2$) was used and foliar fertilization was done with application of urea ($CO(NH_2)_2$) with and without Ekolist. A mixed fertilizer (Ekolist) with a specially-developed chelating complex – chelacid was applied in the experiment. The following were introduced with Ekolist at a rate of 2.0 dm^{-3} ha^{-1} (g dm-3): N – 240.0; K – 130.0; Mg – 40.0; S – 10.0; Cu – 10.0; Zn – 5.0; Mn – 1.0; Fe – 2.0; Mo – 0.04 and B – 10.0.

Table 2

Fertilization diagram

Object	Sum of N [kg ha^{-1}]	Applying time, and type N fertilizer (dose N kg ha^{-1})		
		before sowing	BBCH 23–29	BBCH 31–32
		soil fertilization	foliar fertilization	
1	80	–	(40) $CO(NH_2)_2$	(40) $CO(NH_2)_2$
2	80	–	(40) $CO(NH_2)_2$	(39.76) $CO(NH_2)_2$ + (0.24) Ekolist*
3	120	(40) NH_4NO_3	(40) $CO(NH_2)_2$	(40) $CO(NH_2)_2$
4	120	(40) NH_4NO_3	(40) $CO(NH_2)_2$	(39.76) $CO(NH_2)_2$ + (0.24) Ekolist*

$CO(NH_2)_2$ – urea; NH_4NO_3 – ammonium nitrate;
BBCH – Biologische Bundesanstalt, Bundessortenamt und Chemische Industrie
* mixed fertilizer

Cultivation measures for spring triticale were conducted according to the cultivation requirements for this species. After the forecrop was harvested, ridge plowing for winter was performed to improve the soil structure and store post-winter water. Spring measures were limited to shallow tillage starting with harrowing. The next spring measure was phosphorus and potassium fertilization, fertilization with pre-sowing nitrogen rate, cultivating, harrowing, cereal sowing and post-sowing harrowing. Depending on the used variants, the fertilizers were broadcast on the field surface and during the crop's growing season the fertilizers were broadcast at the BBCH 23–29 stage and applied to foliage at the BBCH 31–32 stage. The harvest was carried out within the first ten days of August with a plot harvester.

Temperature and precipitation measurements were conducted during the experiment. The average temperature was similar in both years of research and the monthly temperature distribution did not diverge from the averages from the multi-annual period (Table 3). The low precipitation in April deserves special attention. In May 2011, the precipitation (51.1 mm) was close to the averages from the multi-annual period and in 2010 (131.9 mm) it exceeded the average precipitation totals for the multi-annual period by more than twice. A higher precipitation total was recorded from July to August compared to the multi-annual period. The month of July 2011, in which the precipitation was very high (202.0 mm), deserves special attention.

Table 3

Weather conditions during the study

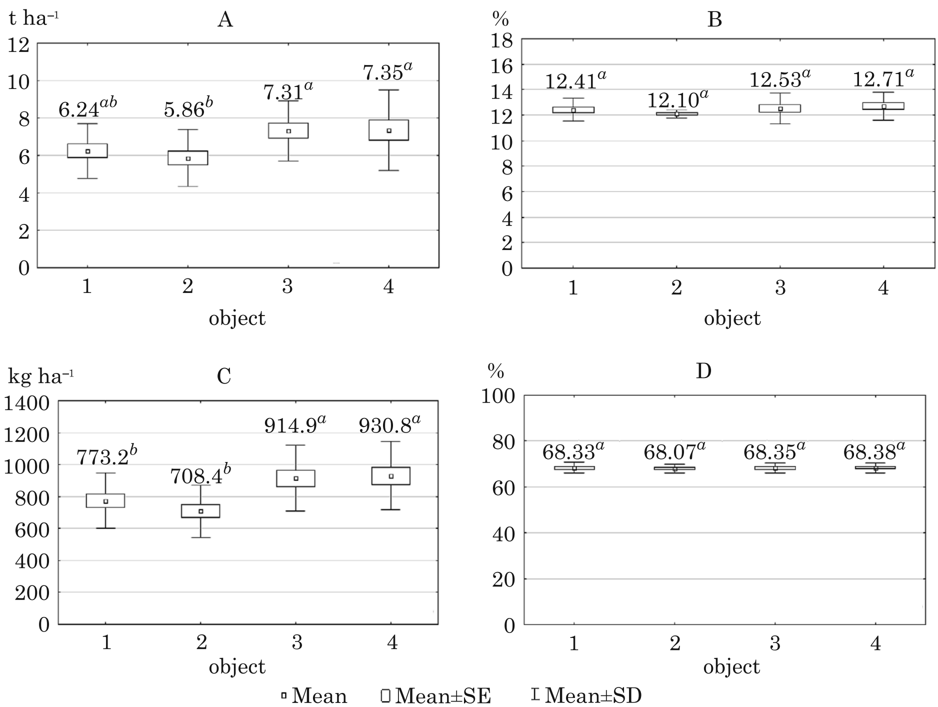
Year	March	April	May	June	July	August	Average March--August
	Temperature (°C)						
2010	2.1	8.1	12.0	16.4	21.1	19.3	13.2
2011	1.6	9.1	13.1	17.1	17.9	17.6	12.7
Reference period*	1.2	6.9	12.8	15.9	17.8	17.7	12.1
Precipitation (mm)							
2010	36.7	18.2	131.9	84.8	80.4	95.3	74.6
2011	16.3	22.5	51.1	81.7	202.0	82.1	75.9
Reference period*	27.6	35.7	51.9	78.5	75.1	66.1	55.8

* Monthly temperature and precipitation average in the period 1961–2005

Grain was harvested, dried and cleaned annually during the experiment. Yields were determined and samples were collected and chemically analyzed for macronutrient content by methods used in the agricultural chemistry. Grain samples were wet-mineralized to determine the macronutrients in H_2SO_4 with an addition of H_2O_2 as the oxidant. Nitrogen was determined by the hypochlorite method (BAETHEN and ALLEY 1989) and phosphorus was determined by the vanadium-molybdenum method. Potassium and calcium were determined by the AES atomic spectrometry method and magnesium was determined by AAS (PANAK 1997) in an AA-6800 Shimadzu apparatus. An Infratec^{TM} 1241 grain analyzer, which uses near infrared analysis in the wavelength range of 570–1100 nm, was used to measure grain starch content. Protein yield was determined by multiplying the grain nitrogen content by a factor of 5.7 and then by grain yield. Analysis of variance, which was consistent with the mathematical model of the experiment arrangement (random blocks) was applied for statistical computations. Average values were determined for individual experimental objects. In addition to the basic statistical parameters, statistically homogeneous groups (groups without differences between average values) were identified using Duncan's test, at the significance level $\alpha = 0.05$. The relationships between grain protein content and grain and protein yield were also analyzed. Excel software and the Statistica statistical package were used to perform the statistical computations and analyses.

Results and Discussion

Milewo variety spring triticale grain yield was from 5.86 to 7.35 t ha^{-1} in own research (Fig. 1A). The applied nitrogen fertilization 120 kg ha^{-1} in the solid form of NH_4NO_3 and $CO(NH_2)_2$ and as foliar application of $CO(NH_2)_2$, without or together with a mixed fertilizer (Ekolist) at the BBCH 31-32 stage, contributed to an increased grain yield. Compared to the standard adopted by COBORU (2013) for spring triticale at an average fertilization level (90 kg ha^{-1}), grain yield was higher by 17.2 to 47.0% in the years 2010–2011. According to REHM (2006) and NADIM et al. (2012), micronutrients needed in trace quantities have a positive effect on the physiological processes of crops, which is reflected in an improved output. The effects of combining nitrogen fertilization with the provision of micronutrients (singly or in the form of mixed fertilizers) have been presented in many papers (KNAPOWSKI et al. 2009, NOGALSKA et al. 2012, WOJTKOWIAK et al. 2014,). In the conducted own research, fertilization with the higher nitrogen rate (120 kg ha^{-1}) together with



1,2... – explanation in the Materials and Methods chapter, averages followed by the same letter are insignificant ($\alpha < 0.05$)

Fig. 1. Grain yield (*A*), protein content (*B*), protein yield (*C*), starch content (*D*)

Ekolist at the BBCH 31–32 stage and without Ekolist contributed to obtaining the highest yield of spring triticale (7.35 t ha^{-1} and 7.31 t ha^{-1}, respectively). Increasing the fertilization level from 80 to 120 kg N ha^{-1} affected an increase in yield spring of triticale by 25.43% after the application of $CO(NH_2)_2$ together with Ekolist and by 17.33% after spraying with a 10% $CO(NH_2)_2$ solution.

Statistical analysis confirmed the effect of nitrogen rates on grain and protein yield (Table 4). Research by LESTINGI et al. (2010) proved that the nitrogen rate for ensuring good triticale grain quality is ca. 50 kg ha^{-1}. Under this rate, grain and protein yield increased by 14.2% and 25.0%, respectively. According to KNAPOWSKI et al. (2009), increasing the fertilization level from 80 to 120 kg N ha^{-1} increased grain yield spring of triticale by 9.6%. According to JANUŠAUSKAITĖ (2013), nitrogen rate of 90–120 kg ha^{-1}, under which grain yield increased by 33.9 and 37.0%, respectively, compared to the object without fertilization, proved optimally economical for achieving a high spring triticale grain yield. The positive effect of higher nitrogen rates, 160–180 kg ha^{-1}, was confirmed in research by CIMRIN et al. (2004) and MUT et al. (2005).

Table 4

Protein, starch content and grain and protein yield of Milewo variety spring triticale

Average for		Grain yield [t ha^{-1}]	Protein content [%]	Protein yield [kg ha^{-1}]	Starch content [%]
Year	2010	$7.12^a \pm 0.85$	$12.21^b \pm 0.37$	$870.0^a \pm 118.5$	$68.08^a \pm 0.95$
	2011	$6.26^b \pm 1.04$	$12.67^a \pm 0.48$	$793.7^a \pm 135.8$	$68.50^a \pm 1.04$
Nitrogen dose [kg ha^{-1}]	80	$6.05^b \pm 0.72$	$12.26^a \pm 0.35$	$740.8^b \pm 85.3$	$68.20^a \pm 1.02$
	120	$7.33^a \pm 0.88$	$12.62^a \pm 0.55$	$922.9^a \pm 97.9$	$68.36^a \pm 1.02$

Averages in columns (separately for years and nitrogen rates) followed by the same letter are insignificant ($\alpha < 0.05$), ±SD

According to KALBARCZYK (2008), a precipitation shortage at the earing-dough stage can cause a decrease in triticale grain yield by 10–20% and at the sowing-dough and sowing-harvest stages by 12–16% and 10–14%, respectively. In the first year of own research, 2.6 times more precipitation was recorded in the period of highest water needs of spring triticale (BBCH 30–39) compared to the 2nd year of research. This affected an increased grain yield by 0.86 t ha^{-1} and decreased protein content by 0.46%.

Depending on the fertilization variants, the average Milewo variety triticale grain protein content was from 12.10 to 12.71% (Fig. 1B) and varied in the years of research (Tab. 4). Protein yield was from 708.4 to 930.8 kg ha^{-1} (Fig. 1C) and depended mainly on grain yield and not on protein content (Fig. 2A, B). Increasing the nitrogen rate from 80 to 120 kg ha^{-1} by soil NH_4NO_3 application contributed to a significant increase in protein yield by 31.4% in the variants with Ekolist and 18.3% in the variants without Ekolist. According to FAGERIA et al. (2009), foliar fertilization does not affect an increased output, but can raise cereal protein content if used during flowering or after flowering. ALARU et al. (2003) claim that the main factor affecting protein content and grain yield is the variety and the least affecting factor is nitrogen fertilization. In that research, nitrogen fertilization used in the tillering phase caused an average increase in triticale grain protein content by 1.57%. In addition, according to WRÓBEL (2005), the application of the second nitrogen rate in a solution form did not have a significant effect on the percentage protein yield content. According to DOMSKA et al. (2009), the action of micronutrients was more efficient in triticale cultivation compared to fertilization with nitrogen alone. In their research, supplementation of basic fertilization with copper, zinc, manganese and Ekolist increased protein yield by 17.9%, 26.8%, 35.3% and 28.1%, respectively. A high grain yield and protein concentration of nitrogen-fertilized spring triticale in the rate range of 90–120 kg ha^{-1} was confirmed by the research of SPYCHAJ-FABISIAK et al. (2005).

Starch is the main reserve material stored in caryopses. Its content in triticale grain is from 62.4–70.9% (BURESOWA 2010). According to LABUSCHAGNE et al. (2007), OBUCHOWSKI et al. (2010) end BECKLES and THITISAKSAKUL (2014), the variety, nitrogen fertilization, location and years of research as well as the internal interaction between these factors have a considerable determining effect on the starch level in triticale grain. In conducted own research, the years of research (Tab. 4) and the fertilizer variants (Tab. 4 and Fig. 1D) did not affect significant changes in grain starch content. On average, irrespective of the years of research and the fertilized objects, Milewo variety spring triticale grain contained from 68.07–68.38% starch (Fig. 1D). NOWOTNA et al. (2007) also did not confirm an effect of nitrogen fertilization on grain starch content. SPYCHAJ et al. (2013) even found a decreased starch content after nitrogen fertilization. A drop in starch content by 2.0 and 3.1% was recorded with increasing nitrogen rates (60–90–120 kg N ha^{-1}). OBUCHOWSKI et al. (2010) also confirm the effect of a lower fertilization level (90 kg nitrogen compared to 140 kg ha^{-1}) on increasing starch content.

It was found, based on regression analysis that an increase in spring triticale grain protein content was not accompanied by a yield increase (Fig. 2). Analysis of the dependence between protein content and grain yield showed a linear dependence. Protein yield increased with the increasing grain yield and the coefficient of determination was close to the linear correlation coefficient (R^2 = 0.936).

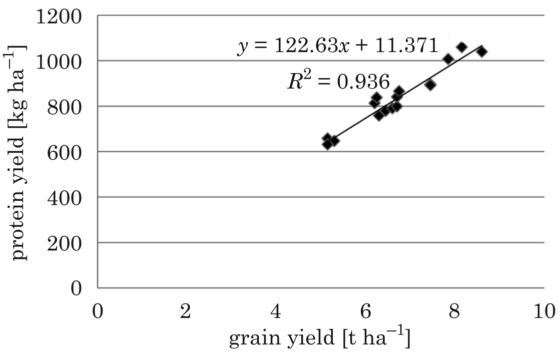


Fig. 2. Dependence of protein yield on grain yield

The content of minerals, among others, such as P, K, Mg, Ca, is crucial for cereal species selection in functional food production (SIDHU et al. 2007). According to MAKARSKA et al. (2010), nutritional value can be improved by the proper selection of parents and selection during breeding work on X *Triticosecale* Wittmack. According to KOWIESKA et al. (2011), spring triticale grain fertilized with nitrogen in the amount from 60 to 100 kg N ha^{-1} differed from wheat in a higher magnesium, potassium and phosphorus content. In own research, statistical analysis confirmed the effect of the years of research and increasing nitrogen rate, from 80 kg to 120 kg on average, on grain phosphorus content (Tab. 5). Nitrogen, potassium content varied in the years of research. Increasing nitrogen rate affected a decrease in magnesium content by 0.18 g kg^{-1} of d.m.

Table 5

Mineral content in Milewo variety spring triticale grain

Average for		Content of minerals [g kg^{-1} of d.m.]				
		nitrogen	phosphor	potassium	calcium	magnesium
Year	2010	21.4^b ± 0.65	4.21^a ± 0.87	4.83^b ± 0.19	1.66^a ± 0.18	1.35^a ± 0.21
	2011	22.2^a ± 0.86	3.28^b ± 0.63	5.12^a ± 0.22	1.61^a ± 0.18	1.22^a ± 0.02
Object	1*	21.8^a ± 0.78	3.12^b ± 0.45	4.98^{ab} ± 0.05	1.54^a ± 0.16	1.33^{ab} ± 0.13
	2	21.2^a ± 0.28	3.13^b ± 0.34	4.99^{ab} ± 0.40	1.66^a ± 0.17	1.41^a ± 0.22
	3	22.0^a ± 1.07	4.23^a ± 0.93	5.14^a ± 0.20	1.75^a ± 0.16	1.18^{ab} ± 0.07
	4	22.3^a ± 0.96	4.50^a ± 0.73	4.79^b ± 0.16	1.60^a ± 0.20	1.22^b ± 0.10
Nitrogen dose [kg ha^{-1}]	80	21.5a ± 0.62	3.12^b ± 0.37	4.98^a ± 0.26	1.60^a ± 0.17	1.38^a ± 0.17
	120	22.1^a ± 0.96	4.36^a ± 0.79	4.97^a ± 0.25	1.68^a ± 0.19	1.20^b ± 0.08

* explanation in the Materials and Methods chapter
Averages in columns (separately for years, objects and nitrogen rates) followed by the same letter are insignificant ($\alpha < 0.05$), ±SD

Spring triticale grain, on average for the fertilizer variants, contained 21.2–22.3 g kg^{-1} nitrogen, 3.12–4.50 g kg^{-1} phosphorus, 4.79–5.14 g kg^{-1} potassium, 1.54–1.75 g kg^{-1} calcium and 1.18–1.41 g kg^{-1} magnesium.

Increasing the fertilization level from 80 to 120 kg N ha^{-1} contributed to increasing phosphorus by 43.8% after foliar application of $CO(NH_2)_2$ together with Ekolist (object 2 compared to 4) and 35.6% after spraying only with $CO(NH_2)_2$ at the BBCH 31–32 stage (object 1 compared to 3). Lack of basic nitrogen fertilization (120 kg N ha^{-1}) and supplementation with Ekolist raised grain potassium content by 7.3% (object 3 compared to 4). Joint application of Ekolist with 80 kg N ha^{-1} (object 2) caused an increased amount of magnesium by 15.6% compared to the higher fertilization level (object 4). According to WOJTKOWIAK et al. (2014), foliar application of $CO(NH_2)_2$ raised phosphorus, calcium and magnesium content in the grain of the Andrus spring triticale variety. According to KNAPOWSKI et al. (2010), increasing the fertilization level from 80 to 120 kg N ha^{-1} caused a significant increase in the amount of nitrogen, phosphorus and potassium in spring triticale grain (by 5.8%, 5.8% and 17.5%, respectively). BOBRECKA-JAMRO et al. (2013) found the highest calcium and magnesium content after the application of 120 kg N ha^{-1}, but without the effect of phosphorus or potassium accumulation in grain as a result of increasing nitrogen rates. According to NOGALSKA et al. (2012), the applied mixed fertilizers showed equal action and variation in chemical composition occurred only between individual years of research.

Conclusions

Summing up, the highest grain and protein yield of Milewo variety spring triticale was obtained after the application of nitrogen fertilization at the rate of 120 kg ha^{-1}. The protein yield increased with the increasing grain yield and the coefficient of determination was close to the linear correlation coefficient. On average, nitrogen rate affected the protein percentage and did not change grain starch content. The years of research and increasing nitrogen rate, from 80 kg to 120 kg on average, affected grain phosphorus content. Nitrogen and potassium content varied only in the years of research. On average, an increasing nitrogen rate affected a decrease in magnesium content. Basic mineral fertilization supplementation with Ekolist in Milewo variety spring triticale cultivation does not indicate the appropriateness of using this mixed fertilizer in practice.

Translated by JOANNA JENSEN

Accepted for print 22.05.2015

References

ALARU M., LAUR U., JAAMA E. 2003. *Influence of nitrogen and weather conditions on the grain quality of winter triticale*. Agron. Res., 1: 3–10.

BAETHEN W.R., ALLEY M.M. 1989. *A manual colorimetric procedure for measuring ammonium nitrogen in soil and plant Kjeldahl digests*. Communications in Soil Science and Plant Analysis, 20: 961–969.

BECKLES D.M., THITISAKSAKUL M. 2014. *How environmental stress affects starch composition and functionality in cereal endosperm*. Starch/Stärke, 66: 58–71.

BOBRECKA-JAMRO D., KRUCZEK G., ROMANIAK M., JARECKI W., BUCZEK J. 2013. *Effect of the dose and method of top – dressing with nitrogen on the yield and quality of winter wheat grain*. Acta Sci. Pol., Agricultura, 12(4): 19–30.

BUREŠOVÁ I., SEDLÁČKOVÁ I., FAMĚRA O., LIPAVSKÝ J. 2010. *Effect of growing conditions on starch and protein content in triticale grain and amylose content in starch*. Plant Soil Environ., 56(3): 99–104.

CIMRIN K., BOZKURT M., SEKEROGLU N. 2004. *Effect of nitrogen fertilization on protein yield and nutrient uptake in some triticale genotypes*. J. Agron., 3(4): 268–272.

COBORU. 2013. http://www.hr-strzelce.pl/index.php/milewo.

DOMSKA D., WARECHOWSKA M., WOJTKOWIAK K., RACZKOWSKI M. 2009.*Wpływ dolistnego dokarmiania mikroskładnikami na plonowanie, zawartość i jakość białka w ziarnie pszenicy i pszenżyta*. Zesz. Probl. Post. Nauk Roln., 538: 49–54.

FAGERIA N.K., BARBOSA FILHO M.P., MOREIRA A., GUIMARES C.M. 2009. *Foliar Fertilization of Crop Plants. Journal of Plant Nutrition*, 32: 1044–1064.

FAO. 2013. *Food and agricultural commodities production.* FAOSTAT. http://faostat.fao.org/site/567/DesktopDefault.aspx?PageID=567#ancor (accessed 16.01.2013).

FAO-WRB. 2006. *World Reference Base for Soil Resources*. World Soil Resources Report. FAO, Rome, Italy, 103: 11-28.

JANUŠAUSKAITĖ D. 2013. *Spring triticale yield formation and nitrogen use efficiency as affected by nitrogen rate and its splitting*. Zemdirbyste-Agriculture, 100(4): 383–392.

KALBARCZYK E. 2008. *Niedobory opadów atmosferycznych ograniczające plony pszenżyta jarego w północno-zachodniej Polsce*. Acta Agrophysica, 11(2): 419–428.

KNAPOWSKI T., KOZERA, MAJCHERCZAK E., BARCZAK B. 2010. *Effect of nitrogen and zinc fertilization on chemical composition and protein field of spring triticale grain*. Fragm. Agron., 27(4): 45–55.

KNAPOWSKI T., RALCEWICZ M., BARCZAK B., KOZERA W. 2009. *Effect of nitrogen and zinc fertilizing on bread-making quality of spring triticale cultivated in Notec Valley*. Pol. J. Environ. Stud., 18: 227–233.

KOCOŃ A. 2009. *Efektywność dolistnego dokarmiania pszenicy i rzepaku ozimego wybranymi nawozami w warunkach optymalnego nawożenia i wilgotności gleby*. Ann. UMCS, Sec. E, 64(2): 23–28.

KOWIESKA A., LUBOWIECKI R., JASKOWSKA I. 2011. *Chemical composition and nutritional characteristics of several cereal grain***.** Acta Sci. Pol. Zootechnica, 10(2): 37–50.

LABUSCHAGNE M.T., GELETA N., OSTHOFF G. 2007. *The Influence of Environment on Starch Content and Amylose to Amylopectin Ratio in Wheat.* Starch/Starke, 59: 234–238.

LESTINGI A., BOVERA F., DE GIORGIO D., VENTRELLA D., TATEO A. 2010. *Effects of tillage and nitrogen fertilization on triticale grain yield, chemical composition and nutritive value.* J. Sci. Food Agric., 90: 2440–2446.

MAKARSKA E., CIOŁEK A., KOCIUBA W. 2010. *Influence of parental forms on changes in the content of mineral elements in grain on new winter triticale hybrid strains*. J. Elem., 15(1): 131–140.

MALAKOUTI M.J. 2008. *The effect of micronutrients in ensuring efficient use of macronutrients*. Turk J. Agric. For., 32: 215–220.

MUT Z., SEZER I., GÜLÜMSER A. 2005. *Effect of different sowing rates and nitrogen levels on grain yield, yield components and some quality traits of triticale.* Asian J. Plant Sci., 4(5): 533–539.

NADIM M.A., AWAN I.U., BALOCH M.S., KHAN E.A., NAVEE K., KHAN M.A. 2012. *Response of wheat (Triticum aestivum L.) to different micronutrients and their application methods*. J. Anim. Plant Sci., 22(1): 113–119.

NOGALSKA A., SIENKIEWICZ S., CZAPLA J., SKWIERAWSKA M. 2012. *The Effect of Multi-Component Fertilizers on the yield and mineral composition of winter triticale*. Pol. J. Natur. Sc., 27(2): 125–134.

NOWOTNA A., GAMBUŚ H., KRATSCH G., KRAWONTKA J., GAMBUŚ F., SABAT R., SABAT R. 2007. *Effect of nitrogen fertilization on the physico-chemical properties of starch isolated from German Triticale varieties*. Starch/Starke, 59: 397–399.

OBUCHOWSKI W., BANASZAK Z., MAKOWSKA A., MAKOWSKA M. 2010. Factors affecting usefulness of triticale grain for bioethanol production. J. Sci. Food Agric., 90: 2506–2511.

PANAK H. 1997. *Metodical Guide to Agricultural Chemistry.* University of Agriculture and Technology, Olsztyn.

REHM G. 2006. *What;s new with micronutrients in our part of the Word?* 2006 Integrated Crop Management Conference – Iowa State University: 181–189.

ROYO C., PARES D. 1996. *Yield and quality of winter and spring triticales for forage and grain.* Grass and Forage Science, 51(4): 449–455.

SANTIVERI F., ROYO C., ROMAGOSA I. 2002. *Patterns of grain filling of spring and winter hexaploid triticales.* Europ. J. Agronom., 16: 219–230.

SIDHU J.S., KABIR Y., HOFFMAN F.G. 2007. *Functional foods from cereal grain*. International J. Ford Prop., 10(2): 231–244.

SPYCHAJ-FABISIAK E., LOZEK O., KNAPOWSKI T., BALCEWICZ M. 2005. *Ocena oddziaływania terminu siewu i nawożenia azotem na wysokość plonu i zawartość białka ogólnego w ziarnie pszenżyta*. Fragm. Agron., 22(1): 550–562.

SPYCHAJ R., GIL Z., BOJARCZUK J. 2013. *Wpływ intensywności uprawy na plonowanie i jakość ziarna nowych linii ozimej pszenicy twardej – wyniki wstępne*. Fragm. Agron., 30(3): 159–171.

WARECHOWSKA M., WARECHOWSKI J., WOJTKOWIAK K., STĘPIEŃ A. 2013. Milling quality of spring triticale grain under different nitrogen fertilization. Pol. J. Natur. Sc., 28(4): 423–435.

WOJTKOWIAK K., STĘPIEŃ A., WARECHOWSKA M., KONOPKA I., KLASA A. 2014. *Effect of fertilisation technique on some indices of nutritional value of spring triticale*. J. Elem., 19(1), 229–242.

WRÓBEL E. 2005. *Wpływ nawożenia azotem na plon i jakość ziarna pszenżyta jarego*. Zesz. Probl. Post. Nauk Roln., 507: 613–620.