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Sławomir STANKOWSKI, Magdalena SOBOLEWSKA, Anna JAROSZEWSKA, Bożena MICHALSKA[1]

IMPACT OF FORM AND DOSE OF NITROGEN FERTILIZERS ON THE TECHNOLOGICAL VALUE OF SPRING TRITICALE *(x Triticosecale Wittm. ex A. Camus)*

WPŁYW FORMY I DAWKI NAWOŻENIA AZOTOWEGO NA WARTOŚĆ TECHNOLOGICZĄ ZIARNA PSZENŻYTA JAREGO *(x Triticosecale Wittm. ex A. Camus)*

Department of Agronomy, West Pomeranian University of Technology, Szczecin, Poland
[1]Department of Meteorology and Shaping Landscape Architecture, West Pomeranian University of Technology, Szczecin, Poland

Streszczenie. Doświadczenie polowe przeprowadzono w latach 2013-2014 w Stacji Doświadczalnej w Lipniku (53º42′ N, 14º97′ S) Zachodniopomorskiego Uniwersytetu Technologicznego w Szczecinie, na glebie lekkiej kompleksu żytniego dobrego. Materiał doświadczalny stanowiło ziarno pszenżyta jarego odmiany ‘Nagano’. Pierwszym czynnikiem doświadczenia był rodzaj nawozu. Zastosowano saletrę amonową, formy azotu amonową i saletrzaną oraz Sulfammo 30 N PRO, formy azotu amonową i amidową. Drugim czynnikiem doświadczalnym były cztery dawki nawożenia azotem: 0 (kontrola), 40, 80, 120 kg N · ha^{-1}. Oznaczono cechy jakościowe ziarna oraz właściwości farinograficzne ciasta. Nie stwierdzono istotnego wpływu zastosowanego rodzaju nawozu azotowego i dawki nawożenia azotowego na: MTZ, ciężar hektolitra, frakcje, liczbę opadania i wskaźnik sedymentacji (test Zeleny’ego) ziarna pszenżyta jarego. Najwięcej białka miało ziarno pszenżyta jarego nawożone dawką 120 kg N · ha^{-1}. Wraz ze wzrostem nawożenia azotem poprawiała się wodochłonność mąki i stabilność ciasta, a zmniejszał stopień rozmiękczenia ciasta. Nawóz Sulfammo 30 N-Pro istotnie polepszył stabilność ciasta w porównaniu z zastosowaną saletrą amonową. Stwierdzono istotne dodatnie korelacje pomiędzy zawartością białka w ziarnie pszenżyta jarego a czasem rozwoju ciasta oraz jego stabilnością.

Key words: spring triticale, nitrogen fertilization, quality traits of grain, farinographic properties of dough.
Słowa kluczowe: pszenżyto jare, nawożenie azotowe, cechy jakościowe ziarna, właściwości farinograficzne ciasta.

INTRODUCTION

The higher protein content and digestibility than in rye, better amino acid composition as compared to wheat, relatively low climate and soil requirements and good lodging and diseases resistance, make triticale a cereal species of great economic importance in the worldwide. In terms of yield and nutritional value, cultivation of triticale can successfully compete with other spring cereals (Wróbel et al. 2000; Jaśkiewicz 2006).

Corresponding author – Adres do korespondencji: Magdalena Sobolewska, Department of Agronomy, West Pomeranian University of Technology, Szczecin, Papieża Pawła VI 3, Szczecin, Poland, e-mail: Magdalena.Sobolewska@zut.edu.pl

Triticale is an interspecies hybrid of wheat and rye, developed mainly for feeding purposes. Numerous, large-scale studies (Bruckner et al. 2013; Bona et al. 2014), confirm that triticale grain is an excellent feed for animals.

Using triticale in the food industry, especially in bread-making, is limited due to a high amylolytic activity and poor rheological properties of its dough (Ceglińska and Haber 2001). However, in opinion of many scientists (Stankowski and Piech 1996; Szymczyk 1999; Ceglińska et al. 2005; Jaśkiewicz 2014) agricultural practices, including nitrogen fertilization, can effectively improve some features of triticale grain, that are important in in the grain processing technology.

In present experiment, the research hypothesis assumes that the baking and technological values of spring triticale grain depends on the form of nitrogen and levels of nitrogen fertilizers applied.

The aim of the study was to evaluate the influence of the fertilizer type and nitrogen nutrition level on baking and technological properties of spring triticale grain *(x Triticosecale Wittm. ex A. Camus)* L., 'Nagano' cv., grown in conditions of Szczecin Lowland.

MATERIAL AND METHODS

Study sites and plant material

The experimental material consisted of spring triticale grain of 'Nagano' cv., originating from an experiment conducted in 2013-2014 at the Agricultural Experimental Station in Lipnik (53º42′ N, 14º97′ S), West Pomeranian Technological University in Szczecin*. A* two factorial field experiment was set on light, good rye complex soil of a IV a soil class. The soil is classified as brown soil developed from light loamy sands, with slightly acidic pH (pH in 1mol KCl – 6.5. The experiment was conducted by means of split-plot design with four replications. The first experimental factor was the type of fertilizer. Ammonium nitrate was used – ammonium and nitrate forms of nitrogen, as well as Sulfammo 30 N PRO – ammonium and amide forms of nitrogen. The second experimental factor was four doses of nitrogen fertilization: 0 (control), 40, 80, 120 kg N · ha^{-1}. The first dose of nitrogen fertilizer was applied before sowing (40 kg · ha^{-1}), second during the shooting stage (40 kg · ha^{-1}), while third at the earing phase depending on fertilizer rate. Phosphorus nutrition in a dose of 50 kg · ha^{-1} and potassium in a dose of 80 kg · ha^{-1} were performed before sowing. Soybean variety 'Augusta' was as a forecrop. The spring triticale grain was sown in the last week of March in the amount of 450 seeds of good germinating rate per square meter, plot area was 15 m^2, sowing was made using mechanical seeding type Ø yord. Triticale harvest was carried out using a combine-harvester in the first decade of August 2013 and 2014. Agricultural practices during triticale cultivation were performed in accordance with recommendations for the crop.

Climatic conditions

The air temperature at the Agrometeorological Station in Lipnik, representing the central part of the Szczecin Lowland, was higher in the growing season 2013 than the long-term value (1961–2000) in all months except September (Table 1).

Table 1. Average monthly air temperature and precipitation in 2013 and 2014, with standard deviation from the norm (1961–2000) at the Agrometeorological Station in Lipnik

Tabela 1. Średnia miesięczna temperatura powietrza i sumy opadów atmosferycznych w latach 2013 i 2014, wraz z odchyleniem od normy (1961–2000) w Stacji Agrometeorologicznej w Lipniku

	Year/deviation Rok/odchylenie	April Kwiecień	May Maj	June Czerwiec	July Lipiec	August Sierpień	September Wrzesień	Mean Średnia IV–IX
Temperature Temperatura [%]	2013	7.7	14.1	16.5	19.2	18.6	12.8	14.8
	deviation from the norm odchylenie od normy	0.3 normal normalny	1.4 slightly warm lekko ciepły	0.6 slightly warm lekko ciepły	1.6 slightly warm lekko ciepły	1.3 slightly warm lekko ciepły	–0.4 normal normalny	slightly warm lekko ciepły
	2014	10.4	12.6	15.6	21.0	17.0	14.9	15.3
	deviation from the norm odchylenie od normy	3.0 anomalously warm anomalnie ciepły	–0.1 normal normalny	–0.3 normal normalny	3.4 anomalously warm anomalnie ciepły	–0.3 normal normalny	1.7 warm ciepły	1.3 very warm bardzo ciepły
	1961–2000	7.4	12.7	15.9	17.6	17.3	13.2	14.0
Rainfall Opady [mm]	2013	25	73	83	93	14	49	337
	the percentage of standard procent normy	66 dry suchy	140 moist wilgotny	134 moist wilgotny	139 moist wilgotny	26 very dry bardzo suchy	104 normal normalny	105 normal normalny
	2014	41	68	43	64	43	84	343
	the percentage of standard procent normy	108 normal normalny	131 moist wilgotny	69 dry suchy	95 normal normalny	80 normal normalny	179 very moist bardzo wilgotny	107 normal normalny
	1961–2000	38	52	62	67	54	47	320

The largest difference (1.6°C) occurred in July, while in May and September, the temperature was higher than standards by 1.4°C and 1.3°C, respectively. Period from May to August was assessed (according to Lorenc (2000) classification based on the standard deviation value) as warm, whereas April and September as typical. The whole period from April to September was estimated as slightly warm in relation to multi-year. In the growing season 2014, the largest positive deviations from the long-term level occurred in July (3.4°C) and April (3.0°C), these months were anomalously warm, while September was warm, because was characterized by temperature by 1.7°C higher than standard. Other months, slightly cooler – small negative deviations (from –0.1°C to –0.3°C) were classified as normal. Six-month period (IV–IX) 2014 was considered very warm.

Precipitation throughout the growing season 2013 exceeded the norm by only 5% (classification according to Kaczorowska1962), hence this period was classified as average. The more varied precipitation conditions occurred in individual month. April, especially August (classified as very dry), were characterized by a shortage of rainfall, and other months, except September, the excess. The most humid of all the analyzed months was September 2014 – rainfall exceeded the norm (179%) by more than half. Slight precipitation deficits (66%) occurred this year in June. The whole growing season 2014, in terms of moisture content, did not deviate from the multi-year norm (Table 1).

Physical and chemical analysis

The thousand grain weight (TGW) was determined according to PN-EN ISO 520 : 2011E. Clean material was placed in an automated grain counter. Quantity of 4 × 250 grains was counted and weighed to the nearest 0.1 g.

The loose density of grains (volume weight) was determined according to PN-EN ISO 7971-1 : 2010P.

Grain size analysis was carried out in accordance with PN-EN ISO 5223 : 2016-02E applying Sortimat Pfeiffer Mess – und Prüfgeräte device equipped in sieves with perforation 1.8 to 2.8 mm, where in the values obtained from sieves 1.8 to 2.2 were summed up.

In order to perform α–amylase activity analysis, the Sadkiewicz device type SWD–SŻ was used, in which measurements of the falling number were carried out by means of Hagberg-Perten method, according to PN-EN ISO 3093 : 2010E. Grain milling was carried out on laboratory roller mill produced by the Research Institute of Baking Industry in Bydgoszcz. The resulting flour was sieved through the laboratory sieve device in order to obtain the appropriate fraction for each analysis, using sieves with a suitable mesh (265 μm – for farinographic assessment, 230 μm – for determination of gluten quantity and quality, 150 μm – for determination of sedimentation index).

Protein content was determined according to PN-EN ISO 20483 : 2014-02E. The conversion coefficient from nitrogen to protein was 5.7.

The sedimentation number was measured according to PN-EN ISO 5529:2010E. The analysis was performed using device consisting of the control panel and shaker of SWD–89 Sadkiewicz type.

Analysis of the farinographic properties of dough was made on the Farinograph Brabender camera using the type 50 head according to PN-EN ISO 5530-1 : 2015-01E.

Following parameters were determined: flour water absorption, dough development time, stability, softening degree after 10 minutes. All samples were analyzed in two replication. The admissible error for determinations of chemical components was 5%.

The results of quantity and quality of gluten are not presented, because of its poor quality in grains of spring triticale, it could not be identified on two different devices in all variants of the experiment.

Statistical analysis

The test results were statistically processed using variance analysis, taking subsequent years of research as the replications. Preliminary analysis showed no interaction between years and experimental factors. Confidence semi-intervals were calculated using Tukey's test at a significance level of $p = 0.05$. To evaluate the relationship between the protein content and selected quality characteristics, simple Pearson correlation coefficients and linear regression was applied.

RESULTS AND DISCUSSION

The quality of the grain, in addition to the genetic features, variety, and applied agricultural technology, is significantly affected by weather conditions (Kołodziejczyk et al. 2009). The course of climatic conditions within the years 2013–2014 was variable (Table 1). In the first and second year of the study, both the average air temperatures and their distribution during the growing season favored the proper development of spring triticale. For high yields light rainfall is required during winter and more rain is needed in April during shooting and flowering stages (Gąsiorowska et al. 2011). According to the literature data (Chmura et al. 2009), the rainfall needs for spring cereals during spring-summer growing season oscillated within 230–300 mm. Moisture conditions in both years were similar, but precipitation distribution in the year 2013 was more favorable for spring triticale during the whole growing season.

The literature is full of positive reviews (Noworolnik and Maj 2005; Leszczyńska and Noworolnik 2008) upon the nitrogen fertilization impact on 1000-grain weight (TGW), that in opinion of Jurga (1994), is a measure of grain plumpness, as a good grain filling provides high flour performance. In the analyzed experiment, there was no significant impact of both the type and level of nitrogen fertilization on the value of TGW (Table 2), which correlates with the results of Podolska (2008). Grain plumpness has an effect on its loose density (Ceglińska et al. 2003a). In our experiment, there was no significant correlation between values of such characteristics of spring triticale grain like test weight and grain fraction vs. applied experimental factors (Table 2). The mean value of the tested feature was 99.9%.

Although not proven statistically significant effect of the type and dose of nitrogen fertilization on falling number and rate of sedimentation Zeleny'ego in the grain tested, there was a tendency to increase both values of these characteristics under the influence of increasing levels of fertilization. The highest values were found in the grain of triticale harvested from plots fertilized with the dose of 80 kg $\cdot$ ha^{-1} (Table 3), which is consistent with data presented by other authors (Podolska 2008), who claim that nitrogen fertilization had no considerable effects on falling number of winter wheat grain. On the other hand, any increase in nitrogen dose caused an increase in sedimentation rate of spelt grain, but these differences were not statistically proven (Podolska et al. 2015). A statistically proven increase in sedimentation index under the increased nitrogen fertilization was confirmed by Stankowski et al. (2008).

Table 2. Effect of fertilizer (F) and its dose (D) on physical properties of triticale grain
Tabela 2. Wpływ nawożenia (F) i dawki (D) na fizyczne właściwości ziarna pszenżyta jarego

Fertiliser Nawożenie	Dose Dawka [kg N · ha^{-1}]	Thousand grain weight Masa tysiąca ziaren [g]	Test weight Ciężar hektolitra [kg · hl^{-1}]	Grain size Wyrównanie ziarna Ø > 2.2 mm [%]
Ammonium sulphate Saletra amonowa	0	39.5	72.1	99.9
	40	40.1	71.7	99.9
	80	39.4	71.8	99.8
	120	39.2	71.9	99.8
Average Średnia		39.5	71.9	99.9
Sulfammo 30 N-Pro	0	38.5	72.1	99.9
	40	38.8	72.2	99.9
	80	39.6	71.9	99.9
	120	38.7	72.4	99.8
Average Średnia		38.9	72.1	99.9
Average Średnia	0	39.0	72.1	99.9
	40	39.4	71.9	99.9
	80	39.5	71.9	99.9
	120	38.9	72.1	99.8
Total average Średnia		39.2	72.0	99.9
$LSD_{0.05}$ for – dla: F		n.s.	n.s.	n.s.
D		n.s.	n.s.	n.s.
D/F		n.s.	n.s.	n.s.

n.s. – not significant difference – różnica nieistotna.

Table. 3. Effect of fertilizer (F) and its dose (D) on quality properties of triticale grain
Tabele 3. Wpływ nawożenia (F) i dawki (D) na jakościowe właściwości ziarna pszenżyta jarego

Fertiliser Nawożenie	Dose Dawka [kg N · ha^{-1}]	Protein content Zawartość białka [%]	Falling number Liczba opadania [s]	Rate of sedimentation Zeleny Wskaźnik sedymentacji Zeleny'ego [cm^3]
Ammonium sulphate Saletra amonowa	0	9.7	108	15.3
	40	9.6	123	17.0
	80	10.8	135	18.1
	120	12.7	118	16.8
Average Średnia		10.7	121	16.8
Sulfammo 30 N-Pro	0	9.9	110	16.2
	40	10.3	128	16.0
	80	10.2	129	17.2
	120	12.1	117	16.3
Average Średnia		10.7	121	16.4
Average Średnia	0	9.8	109	15.8
	40	10.0	126	16.5
	80	10.5	132	17.7
	120	12.4	118	16.5
Total average Średnia		10.7	121	16.6
$LSD_{0.05}$ for – dla: F		n.s	n.s.	n.s.
D		0.48	n.s.	n.s.
D/F		n.s.	n.s.	n.s.

Explanations see Table 2 – Objaśnienia zob. tab. 2.

Grain of cereals grown for the flour production and baking purposes should be characterized by specific parameters in terms of total protein content (Stępniewska and Abramczyk 2013). Its content in cereal grains, thus baking value, also depends, among others, by genetic and environmental factors as well as agricultural treatments, including proper fertilization (Murawska et al. 2014). The triticale grain contains from 9.4 to 13.5% total protein (Warechowska and Domska 2006). Tested grain of spring triticale contained on average 10.7% of protein (Table 3). Among experimental factors analyzed, only nitrogen fertilization dose differentiated its contents. Tested cultivar responded with significant increase in the protein concentration in grains under the influence of increasing doses of nitrogen. Most protein was contained in grain of triticale grown on plots fertilized with the highest nitrogen rate (120 kg · ha^{-1}) (by 26%), which reflects in research made by Jaśkiewicz (2014), who reported remarkable increase in the protein content in winter triticale grain under the influence of increasing nitrogen fertilization.

It is assumed that the water absorption of flour should range from 50 to 60% (Radomski et al. 2007). In the present study, the average water absorption was 50.4% (Table 4).

Table 4. Effect of fertilizer (F) and its dose (D) on farinograph properties of triticale
Tabela 4. Wpływ nawożenia (F) i dawki (D) na farinograficzne właściwości ziarna pszenżyta jarego

Fertiliser Nawożenie	Dose Dawka [kg N · ha^{-1}]	Water absorption Wodochłonność [%]	Development time Czas rozwoju ciasta [min]	Stability Stabilność [min]	Degree of softening Stopień rozmiękczenia [FU]
Ammonium sulphate Saletra amonowa	0	50.4	1.00	1.025	155
	40	49.8	1.03	1.200	122
	80	50.8	1.18	1.125	130
	120	52.3	1.13	1.125	133
Average Średnia		50.8	1.08	1.119	135
Sulfammo 30 N-Pro	0	50.1	1.08	1.250	140
	40	49.7	1.10	1.150	139
	80	50.2	1.15	1.400	130
	120	51.5	1.23	2.025	121
Average Średnia		50.4	1.14	1.456	132
Average Średnia	0	50.2	1.04	1.138	147
	40	49.7	1.06	1.175	130
	80	50.5	1.16	1.263	130
	120	51.9	1.18	1.575	127
Total average Średnia		50.6	1.11	1.288	134
$LSD_{0.05}$ for – dla: F		n.s.	n.s.	0.192	n.s.
D		1.77	n.s.	0.380	8.9
D/F		n.s.	n.s.	0.537	n.s.

Explanations see Table 2 – Objaśnienia zob. tab. 2.

Comparing with the control, after applying nitrogen at the dose of 120 kg · ha^{-1}, flour moisture absorption significantly increased by 3%. There was no significant influence of the type and dose of fertilizer on the time of dough development (Table 4). Dough stability was dependent on both the type of nitrogen fertilizer, rate of the applied nitrogen fertilization, and interaction of these two factors (Table 4). Higher stability characterized dough made of triticale harvested from plots fertilized with Sulfammo 30 N-Pro (by 30%) as compared that made of triticale fertilized with ammonium nitrate. Along with the increase of nitrogen dose, dough stability significantly increased as well. The highest value was recorded at the level of fertilization 120 kg · ha^{-1}, which was increase by 38% as compared to the control. The softening degree of dough depended only on the dose of nitrogen fertilizer applied (Table 4) and it decreased with an increase in the fertilization level. Significantly the lowest value of this trait was found at a level of fertilization 120 kg · ha^{-1} (by 14% as compared to the control). The above test results of farinographic characteristics of dough (Table 4) are partly confirmed by earlier reports (Podolska et al. 2015). Under the influence of increasing nitrogen fertilization doses, above cited authors reported an increase in the value of such features as: flour water absorption, stability, and degree of dough softening.

The yield of spring triticale flour was distinct in the different experimental variants and ranged between 60–70%, as confirm by studies of Children Ceglińska et al. (2003b).

Statistical analysis revealed significant (at the level of p = 0.01) positive correlations between: protein content in spring triticale grain and dough development time (r = 0.0931) and stability (r = 0.688) – Table 5.

Table. 5. Correlation coefficients and regression lines between protein content (x) and quality parameters of triticale grain (n = 16)
Tabela 5. Współczynnik korelacji i regresji liniowej pomiędzy zawartością białka (x) a parametrami jakości ziarna pszenżyta jarego

Dependent variable Zmienna zależna	Correlation coefficient Współczynnik korelacji	Regression line Równanie regresji
Falling number Liczba opadania	0.055	–
Rate of sedimentation Zeleny Wskaźnik sedymentacji Zeleny'ego	0.183	–
Water absorption Wodochłonność	0.931**	y = 42.8 + 0.729 x
Development time Czas rozwoju ciasta	0.688**	y = 0.624 + 0.0458 x
Stability Stabilność	0.423	–
Degree of softening Stopień rozmiękczenia	–0.376	–

** Significant correlation at p = 0.01 – Korelacja istotna przy p = 0,01.

CONCLUSIONS

1. The applied nitrogen fertilizer type and nitrogen fertilization rate did not significantly influence TGW, test weight, grain size distribution, falling number and Zeleny index of the spring triticale grain.
2. With increasing nitrogen fertilization level the protein content significantly increased in grain. The highest proteins had grain of spring triticale fertilized with 120 kg N · ha^{-1}.
3. Rheological properties depended significantly on the applied fertilization rate. The increasing nitrogen fertilization dose improved the water absorption of flour and dough stability, while reducing the degree of dough softening.

4. As compared to the ammonium nitrate, Sulfammo 30 N-Pro significantly improved the dough stability.
5. There were significant, positive correlations between: protein content in spring triticale grain and dough development time and its stability.

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Abstract. The field experiment conducted in 2013–2014 at the Agricultural Experimental Station in Lipnik (53º42′ N, 14º97′ S), West Pomeranian Technological University in Szczecin, on light, good rye complex soil. The experimental material consisted of spring triticale grain of

'Nagano' cv. The first experimental factor was the type of fertilizer. Ammonium nitrate was used, ammonium and nitrate forms of nitrogen, as well as Sulfammo 30 N PRO, ammonium and amide forms of nitrogen. The second experimental factor was doses of nitrogen fertilization: 0 (control), 40, 80, 120 kg N · ha^{-1}. Determined the selected physico-chemical quality traits of grain and farinographic properties of dough. No significant effect of the applied nitrogen fertilizer type and nitrogen fertilization dose was observed on: TGW, test weight, grain fraction, falling number and Zeleny index of the spring triticale grain,. The highest content of proteins were in grain of spring triticale fertilized with the dose of 120 kg N · ha^{-1}. The increasing nitrogen fertilization increased the water absorption of flour and dough stability, while reduced the degree of dough softening. Sulfammo 30 N-Pro significantly improved the dough stability as compared to the ammonium nitrate. There were significant, positive correlations between: protein content in spring triticale grain and dough development time and its stability.