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Original Research

Effect of Nitrogen and Zinc Fertilizing on Bread-Making Quality of Spring Triticale Cultivated in Noteć Valley

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Abstract

In our studies the highest mean significant yield of spring triticale grain of the Kargo variety was obtained following the application of 120 kg N·ha^{-1} and after the foliar application of the highest dose of zinc, as compared to the examined lower levels of fertilization. The used variable fertilization with nitrogen applied to the soil and the foliar application of zinc, on average, resulted in a significant increase in the content of total protein in spring triticale grain of the Kargo variety. The values of the most important baking indices determined for spring triticale manifested growing tendencies within the entire range of the applied doses of nitrogen and zinc. On average, the highest significant content of wet gluten was obtained following the application of 120 kg N·ha^{-1}, and of the highest dose of zinc as compared to, respectively, the dose of 80 kg N·ha^{-1} and to control.

Keywords: spring triticale, nitrogen fertilization, zinc fertilization, grain yield, bread-making quality

Introduction

According to Maćkowiak [1], due to extensive biological progress spring triticale became the fifth (in sequence) principal species of cereals grown in Poland. The area of its cultivation increases every year, amounting to 734,000 ha in 2001 and 1,200,000 ha in 2005 [2]. Nevertheless, the knowledge of agrotechnical procedures employed in the cultivation of triticale varieties still requires more accurate determinations, related in particular to its new varieties and the desirable natural-agricultural conditions. Few scientific reports deal with the relationship between its qualitative traits and the location of its cultivation in Poland [3]. The main application of triticale grain has been fodder production, but at present the interest in triticale is increasing in the food industry in which, as stated by Warechowska and Domska [4] and Boros [5], it is applied, among others, as a raw material in producing flour and bread. The advantages of using triticale in the food industry involve its nutritive value, milling and baking, which may reflect nitrogen fertilization and the application of microelements [6, 7]. Microelements control the biochemical processes developing in plants during their growth, increasing the efficacy of fertilization with macroelements and preconditioning growth and the high biological value of the yield [8]. Thus, their deficiency may alter the qualitative traits of their yield in cultivated plants and cereals in particular, in which the content and quality of protein provide one of the most important criteria of grain nutritional quality. In view of the above, studies have been undertaken on the effect of nitrogen fertilization and of the foliar application of zinc on the size of the yield and on technological indices of grain and flour in spring triticale, the variety of Kargo.

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Table 1. Physicochemical properties of soil.

Parameter			Range	Mean
Total N		$g{\cdot}kg^{-1}$	0.75 – 0.89	0.82
Organic C			6.96 – 8.64	7.85
Available	P	$mg{\cdot}kg^{-1}$	69.93 – 83.79	78.27
	K		178.85 – 218.86	205.91
	Mg		51.65 – 94.70	76.00
	Zn		316.94 – 13.79	8.76
	Cu		5.5 – 7.1	6.4
	Mn		205.3 – 417.8	380.21
pH in KCl			6.3 – 7.0	6.7
Hydrolytic acidity		$mmol(+){\cdot}kg^{-1}$	11.9 – 17.5	14.9

Materials and Methods

The present research involved a two-factor field experiment carried out over 2005-07 at the Agricultural Experiment Station of the University of Technology and Life Sciences at Minikowo, the Kujawy and Pomorze Province, set up following the randomized split-plot design. The plant tested was 'Kargo' spring triticale (certified material – C1) which was grown under the conditions of varied fertilization with nitrogen and foliar fertilization with zinc. The research covered two nitrogen doses (factor I, n=2), accompanied by a varied foliar fertilization with zinc (factor II, n=3). The experiment was carried out in three reps on a typical brown podzolic soil, representing good wheat complex, according to the FAO-UNESCO international classification – Albic Luvisols.

The soil reaction was neutral and the average contents of phosphorus, potassium and magnesium point to very high or high richness of soil in these nutrients. Detailed physicochemical properties of soil on which triticale was grown are given in Table 1. 'Kargo' spring triticale seeds sown were treated with ORIUS 060 FS dressing (60 g of active substance per 1 liter) at plant density of 5.5 $mln{\cdot}ha^{-1}$. The plots, 20 m^2 in size, were fertilized with two nitrogen doses: 80 kg $N{\cdot}ha^{-1}$ (N_{80}) and 120 kg $N{\cdot}ha^{-1}$ (N_{120}) and three zinc doses: Zn_0 (without zinc), Zn_1 (0.1 kg $Zn{\cdot}ha^{-1}$) and Zn_2 (0.3 kg $Zn{\cdot}ha^{-1}$) with constant phosphorus fertilization at a dose of 60 kg $P_2O_5{\cdot}ha^{-1}$ and potassium dose of 120 kg $K_2O{\cdot}ha^{-1}$. The entire fertilization, 46% triple superphosphate and 57% of potassium salt, were applied pre-sowing. Nitrogen fertilization was provided in the form of 46% carbamide on the following dates:

- doses of 80 kg $N{\cdot}ha^{-1}$ (N_{80}) were divided into 40 kg applied before sowing and 40 kg applied epiphytically in the middle of the stalk-shooting phase (phase 34 according to the Zadox scale);
- doses of 120 kg $N{\cdot}ha^{-1}$ (N_{120}) were divided into 40 kg applied before sowing, 40 kg applied epiphytically in the full stalk-shooting phase (phase 34, according to the Zadox scale) and 40 kg applied epiphytically at the beginning of the earing phase (phase 50-51 according to the Zadox scale).

Foliar fertilization with zinc was applied in the form of $ZnCl_2$. The plants were sprayed when triticale reached the full shooting phase (phase 34, according to the Zadox scale). The procedure was implemented within a single day, dissolving respectively the appropriate salt and zinc doses in the water volume to be sprayed at 300 $dm^3{\cdot}ha^{-1}$. The forecrop for spring triticale (Kargo variety) involved oat harvested to yield grain. All the agricultural procedures, sowing and harvesting spring triticale, were conducted consistent with the optimum agrotechnical requirements for the species.

Representative samples of the grain were collected to establish the values of the following parameters:

- falling number (according to Hagberg, PN-ISO-3093),
- total protein (according to Kjeldahl),
- wet gluten content (PN-A-74-043),
- sedimentation value (according to Zeleny, PN-ISO-5529).

The values of baking parameters were determined consistent with the binding standards, using specialist instruments which exhausted the international standards of the International Association for Cereal Science and Technology, ICC [9].

Table 2. Weather conditions in 2005-07 vegetation seasons.

Month	2005		2006		2007		Mean 1995-2005	
	Temperature (ºC)	Rainfall (mm)	Temperature (ºC)	Rainfall (mm)	Temperature (ºC)	Rainfall (mm)	Temperature (ºC)	Rainfall (mm)
IV	8.0	23.8	7.7	66.0	8.5	17.6	8.2	29.3
V	12.7	86.1	12.4	58.8	13.8	73.1	13.4	53.2
VI	14.8	30.2	17.1	22.7	18.2	105.5	16.2	48.4
VII	18.6	43.2	21.0	46.1	18.0	104.7	18.3	77.9
VIII	16.5	43.1	17.0	112.9	17.8	42.1	18.4	59.5
Mean; Total	14.1	226.4	15.1	306.5	15.2	343.0	14.9	268.3

Table 3. Yield of spring triticale grain (Kargo variety) [t·ha^{-1}].

<table>
<tr><td colspan="3">Fertilization level [kg·ha^{-1}]</td><td rowspan="3">Mean</td></tr>
<tr><td rowspan="2">Zn (II factor)</td><td colspan="2">N (I factor)</td></tr>
<tr><td>80 (N_{80})</td><td>120 (N_{120})</td></tr>
<tr><td>0.0 (Zn_0)</td><td>4.47</td><td>5.18</td><td>4.83</td></tr>
<tr><td>0.1 (Zn_1)</td><td>5.14</td><td>5.52</td><td>5.33</td></tr>
<tr><td>0.3 (Zn_2)</td><td>5.70</td><td>6.07</td><td>5.89</td></tr>
<tr><td>Mean</td><td>5.10</td><td>5.59</td><td>5.35</td></tr>
</table>

$LSD_{p=0.05}$	I	II	I x II	II x I
	0.10	0.38	n.s.	n.s.

Table 4. Significant correlation coefficients of the direct correlation between the examined traits of spring triticale.

Parameter	Fertilization N	Fertilization Zn	1	2	3	4	5
Grain yield (1)	n.s.	0.50	-	- 0.50	0.74	n.s.	n.s.
Falling number (2)	n.s.	n.s.	- 0.50	-	n.s.	n.s.	n.s.
Protein content (3)	0.53	0.71	0.74	n.s.	-	0.60	0.58
Gluten content (4)	0.60	n.s.	n.s.	n.s.	0.60	-	n.s.
Sedimentation value (5)	0.64	n.s.	n.s.	n.s.	0.58	n.s.	-

The research results were verified statistically with Statistica software, with analysis of variance according to the model compliant with the experimental design, facilitating the evaluation of the significance of differences with the Tukey test. In order to define the compounds and relationships between nitrogen fertilization, foliar fertilization with zinc and the research results of the qualitative spring triticale traits, the results were exposed to the analysis of simple correlation and linear regression. The non-significant values were eliminated at the significance level of p=0.05.

Weather conditions throughout the experiment (2005-07 growing seasons) are given in Table 2. In the first year of the experiments both the mean air temperature and the total rainfall were lower, as compared with the 1995-2005 means, respectively, by 0.8ºC and 41.9 mm, which accounted for 15.6%, while in 2006 and 2007 mean air temperature and total rainfall were higher than the multi-year means by 0.2ºC and 0.3ºC, and 38.2 mm, which accounted for 14.2% and 74.7 mm, namely 27.8%. Over the intensive triticale growth, especially in May 2005 and 2007, the rainfall was 1.5-fold higher than over the multi-year period. Similarly, the values recorded in June and July 2007 and in August 2006 exceeded the mean values. The air temperature in April and May 2005 and 2006 demonstrated lower, and in April, May and June 2007 – higher mean values, as compared with the 1995-2005 means. In July 2005 and 2006 mean air temperature was higher and in 2007 – lower, as compared with the multi-year value. On the other hand, August recorded lower mean temperatures, as compared with the multi-year values.

Results and Discussion

The variables that determine the yield size of spring triticale include the genetic traits of individual varieties. In the studies performed by Starczewski et al. [10] and by Wróbel [11] on varieties of spring triticale, the mean grain yield amounted to 5.46 t·ha^{-1} (Jago), 5.30 t·ha^{-1} (Maja) and 5.12 t·ha^{-1} (Gabo). A lower mean value of the yield was noted in studies performed by Spychaj-Fabisiak et al. [12], and it amounted to 2.69 t·ha^{-1} for the Gabo variety. In the present studies, on the other hand, the mean grain yield for spring triticale of the Kargo variety was similar to the yield of 5.87 t·ha^{-1} obtained by Ścigalska et al. [3] and was relatively high, reaching 5.35 t·ha^{-1} (Table 3). The yield-augmenting effect of nitrogen was widely documented in the literature but no agreement has been reached as to the optimum dose of the component for triticale [7, 10, 12-14]. Wojciechowski et al. [15] found that spring triticale reacted by a significant gain in grain yield when the dose of nitrogen increased from 80 to 120 kg·ha^{-1}. In the present study, doses of nitrogen fertilization increasing from 80 kg to 120 kg·ha^{-1} also provided a moderately significant increase in grain yield.

Table 5. Effect of fertilization with nitrogen and zinc on the values of technological parameters of spring triticale of the Kargo variety (the means for three years).

Parameter	Fertilization Zn (2 factor) [kg·ha^{-1}]	Fertilization N (1 factor) [kg·ha^{-1}]		mean	$LSD_{p=0.05}$ for:			
		80 - N80	120 - N120		I	II	I x II	II x I
Falling number [s]	0 - Zn_0	178	205	191	n.s.	22.3	n.s.	n.s.
	0.1 - Zn_1	197	228	212				
	0.3 - Zn_2	214	234	224				
Mean		196	222	209				
Protein content [g·kg^{-1}]	0 - Zn_0	111	119	115	2.0	2.7	n.s.	n.s.
	0.1 - Zn_1	119	126	122				
	0.3 - Zn_2	125	131	128				
Mean		118	125	122				
Gluten content [%]	0 - Zn_0	19.8	23.0	21.4	2.62	2.50	n.s.	n.s.
	0.1 - Zn_1	21.4	25.1	23.2				
	0.3 - Zn_2	21.9	27.0	24.4				
Mean		21.0	25.0	23.0				
Sedimentation value [cm^3]	0 - Zn_0	26.2	28.5	27.3	n.s.	n.s.	n.s.	n.s.
	0.1 - Zn_1	26.7	29.5	28.1				
	0.3 - Zn_2	27.3	29.3	28.3				
Mean		26.7	29.1	27.9				

The peak values of the yield were obtained when the applied fertilization reached a dose of 120 kg N·ha^{-1}, i.e. a dose higher by 9.6% than that applied in the experimental conditions of N_{80} (Table 3). As provided by Koziara [16], Rakowski [17], Sekeroglu and Yimez [18], and Mut et al. [7] the doses of 100 kg N·ha^{-1} and 120 kg N·ha^{-1} proved to be significant for the value of the discussed triticale trait. In turn, in the studies of Wróbel [11] and those of Maćkowiak et al. [13], spring triticale reacted by a significant gain in grain yield up to the dose of 90 kg N·ha^{-1}, while Spychaj-Fabisiak et al. [12] obtained statistically significant differences in the yield of spring triticale grain using 60 kg N·ha^{-1}.

The performed analysis of variance and the calculated coefficient of direct correlation (r=0.50) showed that variable foliar fertilization with zinc significantly modified the yield of spring triticale grain of the Kargo variety (Tables 3 and 4). On average, its highest value was obtained using the Zn_2 experimental conditions (5.89 t·ha^{-1}) and the value was higher than those obtained using the Zn_1 or Zn_0 conditions by 10.5% and 21.9%, respectively. In the studies of Domska et al. [19], in which zinc was applied in doses of 5 kg or 10 kg Zn·ha^{-1}, a significant increase in grain yield was obtained only when a lower dose of the microelement was applied.

The falling number defines amylolytic activity and thus the suitability of the studied grain for further use. In the studies of Cegl\'inska et al. [20, 21] on phyli and the varieties of spring triticale grain amylolytic activity, expressed by the falling number, ranged within the compartments of, respectively, 62 s to 113 s, and 83 s to 139 s. The high scope of variation in the discussed trait in triticale was also indicated by the results obtained by Boros [5], Karczmarczyk et al. [22], Warechowska [23], Tohver et al. [24] and Marciniak et al. [25]. In the present studies the mean value of the falling number amounted to 209 s (Table 5), which did not correspond to the results obtained by Ceglińska et al. [20, 21], in which the value of the discussed trait for the Kargo variety amounted to 91 s and 125 s, respectively. Gil and Narkiewicz-Jodko [26] concluded that such a wide range of variations in the sedimentation value (condition of the amylase-starch system in triticale flour) may reflect the marked effect of weather conditions.

Gil and Narkiewicz-Jodko [26] were of the opinion that small doses of nitrogen introduced to soil (30 kg·ha^{-1}) induce an increase in the value of the falling number for spring triticale grain, while high doses are associated with the increased activity of α-amylase, which has been confirmed by the studies of Karczmarczyk et al. [22]. In experiments with spring triticale of the Maja variety conducted by Warechowska [23], an increase in the level of nitrogen fertilization from 80 to 120 kg·ha^{-1} induced a decrease in the value of the falling number in one year of the studies, but an increase in value in the two subsequent years. Similar

Table 6. The regression and determination coefficients (d) for the relationships between nitrogen fertilization (x) and parameters (y).

Parameter	y = ax + b		
	a	b	d (%)
Protein content	0.180	103.59	28.09
Gluten content	100	13.04	36.00
Sedimentation value	0.058	22.07	29.16

relationships have been disclosed in this experiment, in which fertilization with nitrogen increased from 80 to 120 $kg \cdot ha^{-1}$ has decreased α-amylase activity (increased falling number), although in this case the alteration has not been statistically proven (Table 5).

The analysis of variance demonstrated that foliar fertilization with zinc exerted a significant effect on the value of the falling number (Table 5). The highest mean value of the falling number was noted after the application of zinc at the dose of 0.3 $kg \cdot ha^{-1}$, and it was significantly higher, by 17.3%, as compared with the control (Table 5). On the other hand, in experiments of Warechowska [23], with the foliar application of zinc on spring triticale in doses of 0.2 $kg \cdot ha^{-1}$ or 0.4 $kg \cdot ha^{-1}$ in the course of two years of the experiment, an augmented falling number was observed only following the application of 0.2 kg Zn $kg \cdot ha^{-1}$. Foliar fertilization with higher doses of zinc decreased the value of the qualitative trait [23].

Triticale belongs to the species with a relatively high protein content, the amount of which is genetically determined. In the studies of Wróbel [11] and of Spychaj-Fabisiak et al. [12], spring triticale of the Gabo variety manifested the mean content of the parameter at the level of, respectively, 137 $g \cdot kg^{-1}$ and 119 $g \cdot kg^{-1}$. In our experiment, independent of the examined variables, the mean total protein content in the grain of spring triticale, Kargo variety, amounted to 122 $g \cdot kg^{-1}$ (Table 5) and was higher than the value obtained for the variety by Ceglińska et al. [20, 21].

The analysis of variance and the coefficient of direct correlation (r=0.53) have allowed us to conclude that the variable nitrogen fertilization significantly affected the total protein content of the grain (Tables 4 and 5), consistent with the results obtained by other authors [7, 12, 13, 15, 18, 26, 27]. The increase in nitrogen fertilization from 80 to 120 $kg \cdot ha^{-1}$ resulted in a significantly increased protein content in the grain, by 7 $g \cdot kg^{-1}$ (5.9%). On the other hand, in studies of Wróbel [11] and those of Spychaj-Fabisiak et al. [12] significant alterations in the protein content were induced by doses at the level of, respectively, 90 kg $N \cdot ha^{-1}$ and 120 kg $N \cdot ha^{-1}$, as compared to the lower intensity of the fertilization.

On the basis of the linear regression equation (Table 6) it could have been calculated that at the increased nitrogen fertilization dose, e.g. by 10 $kg \cdot ha^{-1}$, the total protein content in grains of the studied spring triticale variety may increase by 1.8 $g \cdot kg^{-1}$.

The foliar application of zinc significantly changed total protein content in the grains of spring triticale, Kargo variety (Table 5). This was confirmed by the significantly positive coefficient of the direct correlation (r=0.71; Table 4). On average, the peak protein content was obtained for the Zn_2 variable (128 $g \cdot kg^{-1}$) and, as compared to the remaining variables (Zn_0 and Zn_1) it was higher by 11.3% and 4.9%, respectively. The applied variable fertilization with zinc in experiments of Domska et al. [19], similar to our studies, significantly affected the total protein content in grains of spring triticale. Warechowska [23] used the foliar zinc fertilization of spring triticale at doses of 0.2 $kg \cdot ha^{-1}$ and 0.4 $kg \cdot ha^{-1}$ and detected a significant increase in the content after two years of the experiment. On the other hand, Domska and Wojtkowiak [4], applying zinc sprays to the soil at doses of 5 or 10 $kg \cdot ha^{-1}$, obtained no directional changes in the total protein content in grains of spring triticale.

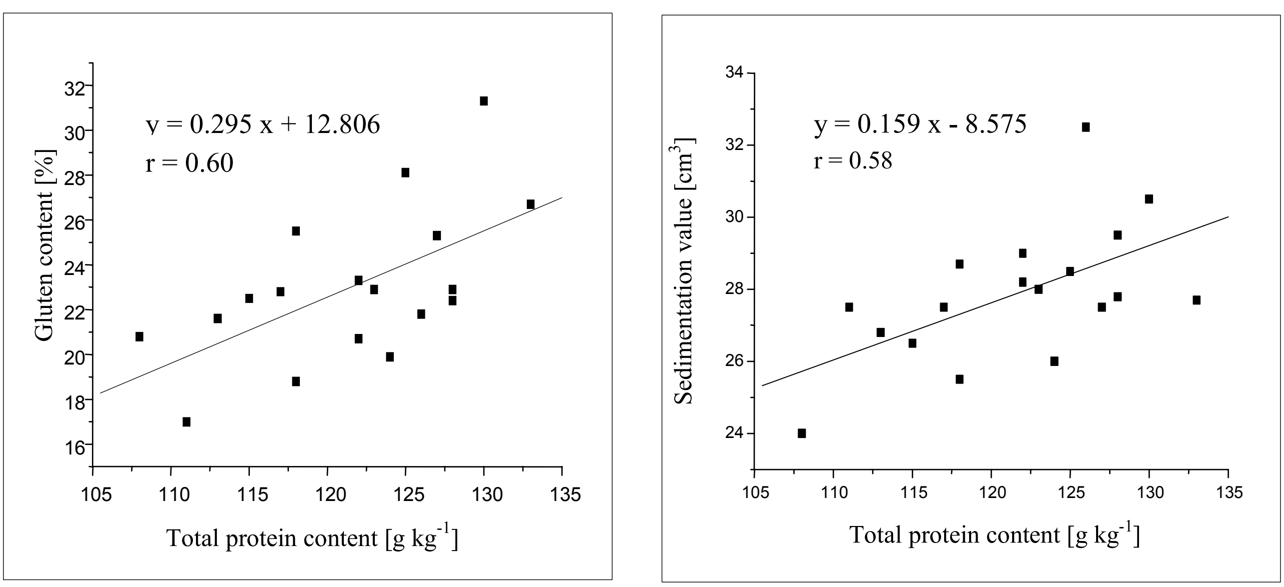

Fig.1. Relationships between the protein content and the content of wet gluten and the sedimentation value of spring triticale.

Total protein content in the grain has shown a significant, positive correlation with the content of wet gluten (r=0.60) and with the sedimentation value (r=0.58) (Table 4). Regression equations calculated for the above relationships are presented in Fig. 1.

Among several variables that are decisive for the baking suitability of the flour, the quantity and quality of gluten are very important. As shown by the studies of Warechowska [23], Tohver et al. [24] and of Domska et al. [29], the studied triticale varieties manifested a high variety in respect to the quantity of eluted wet gluten. Gil and Narkiewicz-Jodko [26] obtained an average value of the parameter for spring triticale of the Jago variety, at a level of 8.5%, which fails to correspond to our results in which, independently of experimental variables, the mean content of gluten in the grain of the Kargo variety was definitely higher and amounted to 23.0% (Table 5).

The amount of gluten in spring triticale grain significantly increased under the effect of variable nitrogen fertilization (Table 4). In our studies the highest value of this trait was obtained employing the variable N_{120}. It amounted to 25.0% and it was higher by 4.0% as compared to N_{80} conditions. In the studies of Warechowska [23], the content of wet gluten, similar to our studies, increased significantly under the effect of the rising level of nitrogen fertilization (up to 120 kg·ha^{-1}). An analogous rule was noted in the studies of Gil and Narkiewicz-Jodko [26].

In our studies, similar to the results of Warechowska [23], a significant effect was disclosed of variable intensity foliar fertilization with zinc on the gluten content in spring triticale grain of the Kargo variety (Table 5). The abovementioned author obtained the highest amounts of wet gluten in grains collected in control conditions (11.5%), while the increasing level of zinc fertilization was accompanied by a decrease in the technological parameter. The subsequent doses (0.2 kg Zn·ha^{-1} and 0.4 kg Zn·ha^{-1}) decreased the value of the trait to the levels of 10.5% and 7.5%, respectively. This was inconsistent with the results of our experiment, in which the increasing dose of foliar zinc fertilization was followed by the increasing content of wet gluten. It is contradictory to the present results noted where the higher the foliar zinc fertilization dose, the higher the content of wet gluten; it was highest in the case of foliar dose of 0.3 kg Zn·ha^{-1} and it was significantly higher by 3 percentage points, as compared with the control (Table 5).

The sedimentation value allows for a preliminary evaluation of the flour-baking value. Ceglińska et al. [21] expressed the opinion that triticale flours manifest low values of the sedimentation value. In general, they are lower than the sedimentation values obtained for wheat flours. The cause of the difference reflects low content of high molecular weight glutenin in spring triticale flour [25]. In our experiment, independently of experimental variables, the sedimentation value in the flour of spring triticale of the Kargo variety amounted to 27.9 cm^3 (Table 5). The lower values of the sedimentation value in their experiments, amounting to 17.35 cm^3 and 15.8 cm^3, were obtained by, respectively, Tohver et al. [24] and by Gil and Narkiewicz-Jodko [26]. In turn, Cеglińska et al. [20], in their studies on spring triticale varieties, obtained values of the sedimentation value intermediate to those obtained for rye and wheat.

The analysis of variance failed to disclose any significant effect of either the variable level of foliar zinc fertilization or of nitrogen fertilization on the value of the sedimentation value (Table 5). Gil and Narkiewicz-Jodko [26] evaluated the effect of nitrogen fertilization on baking parameters and obtained relatively low values of the discussed trait. They expressed the opinion that the sedimentation value is determined first of all by a plant variety and whether conditions in the studied years [26, 30]. Even if nitrogen fertilization induced a successive increase in the sedimentation value, the alterations were not particularly pronounced.

Conclusions

1. On average, the peak significant increase in the yield of spring triticale of the Kargo variety was obtained following the application of 120 kg N·ha^{-1} and the highest foliar dose of zinc, as compared to the yield obtained following lower fertilization doses.
2. Nitrogen fertilization of a different intensity, applied both to the soil and epiphytically, and the foliar application of zinc resulted in a moderately significant increase in the total protein content in the grain of spring triticale.
3. The values of principal baking indices of the studied variety of spring triticale manifested increasing tendencies for the entire range of the applied nitrogen and zinc doses. The highest and moderately significantly increased content of wet gluten was obtained following the application of 120 kg N·ha^{-1} and the highest dose of zinc, as compared to the dose of 80 kg N·ha^{-1} and to the control.

References

1. MAĆKOWIAK W. Estimation of progress and strategic directions of triticale breeding in Poland, Biul. Inst. Hod. Aklim. Rośl., **230**, 127, **2003**.
2. OLEKSIAK T., ARSENIAK E. Current status of triticale in Poland, Proceedings of 6th International Triticale Symposium, 3-7.09.2006. Stellenbosch, South Africa, 162, **2006**.
3. ŚCIGALSKA B. Crop yield variability of winter and spring triticale cultivars cultivated on good wheat complex soil, Fragm. Agron., XXIV, **4** (96), 204, **2007**.
4. WARECHOWSKA M., DOMSKA D. Comparison of technological usefulness indices and macroelement contents in the grain of some winter triticale cultivars, Fol. Univ. Agric. Stetin., Agricultura **247** (100), 211, **2006**.
5. BOROS D. Titicale of high end-use quality enhances opportunities to increase its value in world cereals market, Proceedings of 6th International Triticale Symposium, 3-7.09.2006. Stellenbosch, South Africa, pp. 118, **2006**.

6. DOMSKA D., WOJTKOWIAK K. The effect of fertilization technique on triticale yield and grain quality, Part. II. Protein content and composition, Zesz. Probl. Post. Nauk Roln., **502**, 51, **2004**.
7. MUT Z., SEZER I., GŰLŰMSER A. 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, **2005**.
8. GRZYŚ R. The role and importance of micronutrients in plants nutrition, Zesz. Prob. Post. Nauk Roln., **502**, 89, **2004**.
9. SADKIEWICZ K., SADKIEWICZ J. Cereal-and-flour processing measurement-and-research devices, Wyd. ATR Bydgoszcz, **1998**.
10. STARCZEWSKI J., STANKIEWICZ CZ., BOMBIK A. Reaction of selected varieties of spring and winter triticale no environmental conditions, Part I, Grain yield, protein content and protein yield, Biul. Inst. Hod. Aklim. Rośl., **216**, 117, **2000**.
11. WRÓBEL E. Effect of nitrogen application on yield and quality of spring triticale grain. Zesz. Probl. Pos. Nauk Roln., **507**, 605, **2005**.
12. SPYCHAJ-FABISIAK E., LOŽEK O., KNAPOWSKI T., RALCEWICZ M. The effect of selected agrotechnical factors on the crop yield, the content and the protein yield in the triticale grain, Fragm. Agron. XXII, **1** (85), 550, **2005**.
13. MAĆKOWIAK W., BUDZANOWSKI G., MILEWSKI G., GOWORKO W., WOŚ H. Comparison of yielding of spring triticale cultivars with spring wheat depending on different level of nitrogen fertilization and sowing rate, Fol. Univ. Agric. Stetin., Agricultura **228** (91), 69, **2002**.
14. NIERÓBCA P. The effect of nitrogen fertilization, sowing time and sowing density on yield and yield components in the spring triticale, Biul. Inst. Hod. Aklim. Rośl., **231**, 231, **2004**.
15. WOJCIECHOWSKI T., BOBRZECKA D., PROCYK Z. The effect of increasing copper rates applied on the background of two doses of nitrogen fertilization on spring triticale yield, Fol. Univ. Agric. Stetin., Agricultura **228** (91), 191, **2002**.
16. KOZIARA W. Yield and seed value of spring triticale depending on irrigation, cultivation system and nitrogen fertilization, Fol. Univ. Agric. Stetin., Agricultura **206** (82), 145, **2000**.
17. RAKOWSKI D. Influence of irrigation and high doses of NPK on some physiological processes and yield of spring triticale, Fol. Univ. Agric. Stetin., Agricultura **206** (82), 237, **2000**.
18. SEKEROGLU N., YILMAZ N. Effect of increasing nitrogen doses on yield and yield components in some triticale lines under dry conditions in Eastern Anatolia, Pak. J. Biol. Sci. **4**, 672, **2001**.
19. DOMSKA D., BOBRZECKA D., WOJTKOWIAK K., WARECHOWSKA M., SOKOŁOWSKI Z. Fertilization effect on yield and grain quality of some spring triticale varieties, Fol. Univ. Agric. Stetin., Agricultura **206** (82), 51, **2000**.
20. CEGLIŃSKA A., CICHY H., HABER T., SADECKA M. Evaluation of bread-making quality of some spring triticales, Biul. Inst. Hod. Aklim. Rośl., **230**, 177, **2003**.
21. CEGLIŃSKA A., CICHY H., CACAK-PIETRZAK G., HABER T., SMUGA W. Utilization of spring triticale to bread production, Fol. Univ. Agric. Stetin., Agricultura **247** (100), 39, **2006**.
22. KARCZMARCZYK S., KOSZAŃSKI Z., ZBIEĆ I., TYRAKOWSKA-BIELEC U. Response of spring triticale to irrigation and mineral fertilization, Part II, Activity of physiological processes, chemical composition and baking value of grain, Fol. Univ. Agric. Stetin., Agricultura **206** (82), 117, **2000**.
23. WARECHOWSKA M. Qualitative evaluation of spring triticale grain fertilized with different nitrogen and zinc doses, Zesz. Probl. Post. Nauk Roln., **502**, 411, **2004**.
24. TOHVER M., KANN A., TÄHT R., MIHHALEVSKI A., HAKMAN J. Quality of triticale cultivars suitable for growing and bread-making in northern conditions, Food Chemistry **89** (1), 125, **2005**.
25. MARCINIAK A., OBUCHOWSKI W., MAKOWSKA A., BUDZYŃSKA K. Possibilities of triticale grain for food industry use, Fragm. Agron., XXIV, **1** (97), 240, **2008**.
26. GIL Z., NARKIEWICZ-JODKO M. Milling and baking quality of spring and winter triticale in relation to nitrogen fertilization and forecrop, Biul. Inst. Hod. Aklim. Rośl. **201**, 133, **1997**.
27. CIMRIN K.M., BOZKURT M.A., SEKEROGLU N. Effect of nitrogen fertilization on protein yield and nutrient uptake in some triticale genotypes, J. Agron., **3** (4), 268, **2004**.
28. BOZKURT M.A., CIMRIN K.M., SEKEROGLU N. The effect of nitrogenous fertilization on nitrogen use properties in some triticale genotypes, Ankara Univ. Facul. of Agric., J. Agric., **7** (3), 35, **2001**.
29. DOMSKA D., WOJTKOWIAK K., WARECHOWSKA M. The effect of fertilization technique on triticale yield and grain quality, Part III, Nutritive and technological values, Zesz. Probl. Post. Nauk Roln., **502**, 61, **2004**.
30. EREKUL O., KÖHN W. Effect of weather and soil conditions on yield components and bread-making quality of winter wheat (*Triticum aestivum* L.) and winter triticale (*Triticosecale* Wittm.) varietes in north-east Germany, J. Agron. Crop Sci., **192** (6), 452, **2006**.