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EFFECT OF FERTILISATION TECHNIQUE ON SOME INDICES OF NUTRITIONAL VALUE OF SPRING TRITICALE GRAIN

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Abstract

Triticale is a cereal which may compete with other species of crop plants in terms of the nutritional value. This grain crop enjoys an increasing popularity among farmers as well as food and animal feed manufacturers, hence there is a growing interest in foliar fertilisation with micronutrients in order to ensure fast and effective nutrition.

This study discusses the effect of soil fertilisation or soil and foliar fertilisation with nitrogen (with or without multi-component fertilisers) on the content of macronutrients (nitrogen, phosphorus, potassium, magnesium and calcium), total protein and protein fractions in the grain of spring triticale of the Andrus cultivar grown in north-eastern Poland. The fertilisation of cv. Andrus spring triticale involved a pre-sowing application of ammonium nitrate, an application of 46% urea in the period of tillering, (with and without the fertiliser Azofoska) and an application of ammonium nitrate as well as a soil and the foliar application of urea (10% solution, with and without an addition of Ekolist Z) in the period of stem shooting. Differentiation of the experimental results on the content of the analysed macronutrients as well as the protein composition was caused by differences of habitat conditions in the two experimental seasons. Higher nitrogen doses applied as a split urea dose resulted in a higher concentration of phosphorus, calcium and magnesium in grain from cv. Andrus spring triticale. The dose of 120 kg N ha^{-1} in ammonia nitrate and urea applied to soil or as foliar spray resulted in an increase of total protein. The accumulation of glutenins in triticale grain usually increased in response to the higher dose of nitrogen (120 kg ha^{-1}) applied both with and without the multi-component fertilisers. The foliar supplementation with urea and micronutrients in multi-component fertilisers contributed to a reduced accumulation of alpha/beta-type gliadins, regardless of the nitrogen dose.

Keywords: spring triticale, fertilization, macroelements, protein composition.

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WPŁYW TECHNIKI NAWOŻENIA NA WYBRANE WSKAŹNIKI WARTOŚCI ODŻYWCZEJ ZIARNA PSZENŻYTA JAREGO

Abstrakt

Pszenżyto uznawane jest za zboże, które może konkurować pod względem wartości odżywczej z innymi gatunkami zbóż i cieszy się coraz większym zainteresowaniem rolników, przetwórców żywności i paszy. Obserwuje się wzrost zainteresowania nawożeniem dolistnym mikroelementami, które zapewnia efektywne i szybkie dostarczenie potrzebnych składników pokarmowych.

W pracy omówiono wpływ nawożenia azotem doglebowo lub doglebowo i dolistnie, bez i z udziałem nawozów wieloskładnikowych, na zawartość makroskładników (azotu, fosforu, potasu, magnezu, wapnia), białka ogółem i frakcji białka w ziarnie pszenżyta jarego odmiany Andrus uprawianego w warunkach północno-wschodniej Polski.

W nawożeniu pszenżyta jarego odmiany Andrus zastosowano przedsiewnie saletrę amonową oraz w okresie krzewienia mocznik 46% bez azofoski lub z azofoską, a w okresie strzelania w źdźbło saletrę amonową, mocznik doglebowo i dolistnie (roztwór 10%) bez dodatku lub z dodatkiem ekolistu Z. Na zróżnicowanie wyników badań, zarówno zawartości makroelementów, jak i białka, w dużym stopniu wpłynęły warunki siedliskowe w latach realizowanego doświadczenia. Wyższy poziom nawożenia azotem z zastosowaniem części dawki mocznika w formie oprysku wpłynął na większą zawartość fosforu, wapnia i magnezu w ziarnie pszenżyta jarego odmiany Andrus. Dawka 120 kg ha^{-1} N w formie saletry amonowej i mocznika wprowadzona doglebowo i dolistnie wpłynęła na zwiększenie zawartości białka ogółem. Pod wpływem większych dawek azotu (120 kg ha^{-1}) zastosowanych bez dodatku i z dodatkiem nawozów wieloskładnikowych zwiększało się przeważnie nagromadzenie glutenin w ziarnie pszenżyta. Dolistne dokarmianie mocznikiem oraz mikroelementami w nawozach wieloskładnikowych, niezależnie od dawki azotu, przyczyniło się do zmniejszenia nagromadzenia gliadyn α i β.

Słowa kluczowe: pszenżyto jare, nawożenie, makroelementy, frakcje białek.

INTRODUCTION

The nutritional value of triticale grain from spring cultivars in comparison to winter ones is distinguished by a higher protein content (PETKOW et al. 2000). Cultivars with a high nutritional value can be bred through the development and appropriate choice of parental forms, selection during the cultivation (MAKARSKA et al. 2010) and implementation of suitable cultivation and agronomic practices.

The content of nutrients is an important quality feature of edible and fodder grains (RACHOŃ, SZUMIŁO 2009). This factor significantly determines the supply of a daily food ratio of nutrients, thus ensuring production of wholesome grain is a high priority in maintaining human and animal health (KONOPKA et al. 2012).

The current situation on the Polish market has stimulated food producers' demand for good quality cereal grain. Triticale is a cereal which may compete with other cereal species in terms of nutritional value. Despite its advantages, this species is grown mainly for animal feeds (HARMONEY, Thompson 2005). None of triticale cultivars is recommended for bread baking, although numerous studies have demonstrated its suitability for this purpose (Tohver et al. 2005). Some research has been carried out to show that triticale grain (like grain of other cereal species) can also be used in the food industry as raw material for flour and bread production (Amiour et al. 2002).

In recent years, there has been an increasing interest in foliar fertilisation with micronutrients, its superiority to soil fertilisation and benefits (particularly in the case of intensive nitrogen fertilisation) (Domska et al. 2009, Knapowski et al. 2012). Since foliar supplementation ensures a fast and effective supply of necessary nutrients, it appears highly appealing and can be recommended in agricultural practice as a cost-effective agricultural factor (Johansson et al. 2001, Wojtkowiak, Domska et al. 2009).

This study discusses the effect of soil or soil and foliar fertilisation with nitrogen, with or without addition of multi-component fertilisers, on the content of macronutrients (nitrogen, phosphorus, potassium, magnesium, and calcium), total protein and protein fractions in grain of spring triticale of the Andrus cultivar grown in the north-eastern Poland.

In the context of the research objectives, a zero hypothesis (H_0) claiming the lack of significant differences among levels of experimental factors was verified. Should the zero hypothesis (H_0) be rejected, a new alternative hypothesis (H_A) would be tested, stating that there were significant differences between the analyzed nitrogen fertilisation techniques, affecting selected quality indices of spring triticale grain.

MATERIAL AND METHODS

In 2010-2011, a field experiment was conducted in the Educational and Research Station of the University of Warmia and Mazury, in Tomaszkowo (53°72′N; 20°42′E). It was set up on typical brown soil with the texture of light loam, developed on the subsoil composed of very fine soil. In the Polish soil valuation system, the soil belonged to class III b. It was characterised by acid reaction, a low content of organic carbon (C_{org}.), a high content of phosphorus and potassium and a medium content of magnesium and calcium.

The experiment was established in a random block design with three replications. The size of a plot was 6.25 m^2, including 4.0 m^2 for harvest. The sowing rate of cv. Andrus grains was 282.1 kg of seeds ha^{-1}, with inter-row spacing of 10.5 cm. The preceding crop was winter triticale.

Fertilisation with phosphorus and potassium was the same for all treatments (30.2 kg ha^{-1} P in the form of triple superphosphate 46% and 83.1 kg ha^{-1} K in potassium salt). Nitrogen fertilisation was differentiated (Table 1). Two doses of nitrogen, 80 and 120 kg N ha^{-1}, were applied and

Table 1

Field experiment design in 2010-2011

Objects	Total N fertilisation (kg N ha^{-1})	Fertiliser type and application time (kg N ha^{-1} dose)		
		before sowing	tillering phase (BBCH 23-29)	stem shooting phase (BBCH 31-32)
1	80	-	urea (40)	urea (40)
2	80	-	urea (20) Azofoska (20)	urea (40)
3	80	-	urea (40)	urea 40*
4	80	-	urea (40)	ammonium nitrate (32) + Ekolist* (8)
5	120	ammonium nitrate (40)	urea (40)	urea (40)
6	120	ammonium nitrate (40)	urea (40) Azofoska (20)	urea (40)
7	120	ammonium nitrate (40)	urea (40)	urea (40)*
8	120	ammonium nitrate (40)	urea (40)	ammonium nitrate (32) + Ekolist*(8)

*foliar fertilisation

each dose were split into 40 kg N ha^{-1} sub-doses. Ammonium nitrate was applied before sowing, and 46% urea (both with and without Azofoska in a dose corresponding to 20 kg of nitrogen) was applied in the tillering period. Fertilisation during the stem shooting phase included an application of ammonium nitrate, urea to soil and sprayed over leaves in 10% solution, without or with Ekolist Z in a dose of 2.0 dm^{-3} ha^{-1}.

The experiment (in treatments 2, 4, 6, 8) was supplemented with multi-component fertilisers containing macronutrients and a set of properly selected micronutrients, as recommended in agricultural practice (Table 2).

Agronomic treatments were performed according to the requirements of spring triticale.

Temperature and precipitation were monitored during the experiment (Figure 1). The mean temperature in both years was similar, and the monthly distribution of temperatures did not differ from the means recorded

Table 2

Composition of the applied multi-fertilisers

Type of multi-fertiliser	N	P	K	Mg	S	Cu	Zn	Mn	Fe	Mo	B
Ekolist (g dm^{-3})	120.0	0.00	65.0	20.00	5.0	5.00	2.500	0.50	1.00	0.02	5.000
Azofoska (%)	13.6	1.83	15.9	2.71	9.2	0.18	0.045	0.27	0.17	0.04	0.045

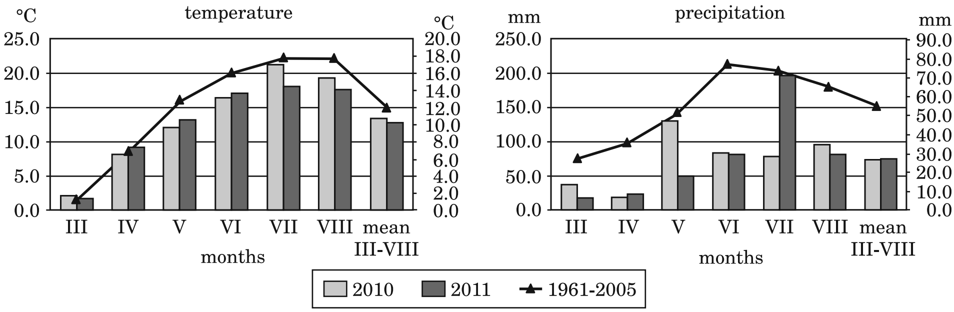

Fig. 1. Meteorological conditions during the investigations

in a multi-year period. Precipitation during the triticale vegetative period was varied. Noteworthy was the scanty rainfall in April. In May 2010, the amount of precipitation was close to the multi-annual mean (51.1), while in 2011, it more than doubled the mean sum of precipitation in the long-term period (131.9 mm). Between July and August, a higher rainfall sum was recorded than in the multi-year period, particularly in July 2011, when precipitation was very high (202 mm).

Each year, after harvest, grain samples were collected and subjected to chemical analyses, using methods applied in agricultural chemistry. Grain samples were wet mineralised in order to determine macronutrients in H_2SO_4 with H_2O_2 added as an oxidant. The following elements were determined: nitrogen – with the hypochlorite method, phosphorus – with the vanadium-molybdenum method, potassium, calcium – by ESA atomic spectroscopy, and magnesium – by ASA, using an AA-6800 Schimadzu apparatus.

Protein fractions were determined according to the method proposed by Wieser at al. (1998). Albumins were extracted with distilled water, globulins with a mixture of NaCl and $HKNaPO_4$, prolamins with 60% ethanol and glutenins in a mixture of 50% propanol-1+2 m urea + tris HCl and 1+ DTE under nitrogen. The determinations were performed on a Hewlett Packard series 1050 instrument. The results were analysed with the use of the HPLC software according to HP 3D ChemStation in mAU·s units. They were converted and presented as percentage values. All determinations were made in two replications.

The statistical calculations consisted of a two-factor variance analysis, compliant with the mathematical model of an experimental layout in random blocks. Mean values and the standard error of the means were determined for individual experimental objects. The calculations took into account the variability of a given feature depending on the year of cultivation, the fertilising technique and the interaction of the factors mentioned. Apart from the basic statistical parameters, statistically homogenous groups were distinguished (groups with no differences between means) using the Tukey's test at the significance level of α=0.05. Excel and Statistica software packages were used to perform the calculations and statistical analyses.

RESULTS AND DISCUSSION

Triticale enjoys an increasing popularity among farmers as well as food and animal feed manufacturers. The research conducted by KAMYAB et al. (2012) confirms a high nutritive value of this cereal species relative to its lower environmental requirements in comparison to wheat.

The spring triticale cultivar called Andrus was entered in the Polish national register of cultivars in 2009, classified into the group of very good, high yielding cultivars.

The content of such nutrients as nitrogen, potassium, phosphorus, calcium or magnesium proves the nutritive value of a cultivated variety (ŚCIGALSKA et al. 2000, KNAPOWSKI et al. 2010). In grain from cv. Andrus grown in 2010-2011 on light soil, fertilised with nitrogen in doses of 80 and 120 kg ha^{-1} applied into soil or into soil and on leafage, with and without an addition of micronutrients (Azofoska and Ekolist), no significant differences were found in the selected mineral components. In general, the chemical composition of the grain varied only slightly, which precludes any firm conclusion about which of the fertilisation technologies was the most effective. This was confirmed by the statistical analysis in both vegetative seasons and on the annual means.

The mean nitrogen content in cv. Andrus triticale grain ranged from 19.40 to 20.87 g kg^{-1} (Table 3). In the first year of cultivation, the highest value of nitrogen was found after the application of urea in two doses of 40 kg ha^{-1} into the soil and foliar application (21.27 g kg^{-1}). Nitrogen fertilisation (80 kg ha^{-1}) in the form of urea (BBCH 23-29) and ammonium nitrate, together with Ekolist (object 4) in the two years of cultivation contributed to an increase in the nitrogen accumulation in grain compared to the higher level of fertilisation (object 8). An increase in the nitrogen fertilisation to 120 kg and supplementation with a multiple-component fertilisers did not lead to an increase in the nitrogen content in grain, unlike in the research conducted by other authors (SZPUNAR-KROK et al. 2006, KNAPOWSKI et al. 2010). This could have been caused by the unfavourable weather conditions in the two years. In the current experiment, no significant differences were found in the content of potassium, magnesium and, in most cases, phosphorus and calcium between the experimental variant fertilisation treatments. According to ŚCIGALSKA et al. (2000), the concentration of macronutrients is a cultivar-specific characteristic. In our research, the levels of potassium, calcium and magnesium were higher and the level of phosphorus was lower than given in the charts showing nutritive values of cereals produced in Poland (IZ PIB – INRA 2009). Moreover, in the research conducted by KNAPOWSKI (2010), the values for potassium and calcium in spring triticale cultivar Kargo were lower. In our experiment, the grain of cultivar Andrus was characterised by a higher level of potassium and calcium and a lower level of phosphorus than grain of spring wheat Torka and Tonacja cultivars

Table 3

Content of macronutrients in grain of cv. Andrus spring triticale

Years	Objects	(g kg^{-1} of d.m.)				
		nitrogen	potassium	phosphor	calcium	magnesium
2010	1	20.93 ^{bc} ± 0.82	5.97 ^{c} ± 0.55	3.56 ^{bc} ± 0.13	1.48 ^{ab} ± 0.09	1.44 ^{abc} ± 0.02
	2	20.81 ^{abc} ± 0.65	5.42 ^{abc} ± 0.12	3.5 ^{b} ± 0.15	1.35 ^{a} ± 0.10	1.44 ^{abc} ± 0.08
	3	21.27 ^{c} ± 0.19	5.3 ^{ba} ± 0.05	3.69 ^{bcde} ± 0.11	1.35 ^{a} ± 0.06	1.59 ^{bc} ± 0.14
	4	20.80 ^{abc} ± 0.24	5.63 ^{bc} ± 0.15	3.81 ^{c} ± 0.20	1.35 ^{a} ± 0.08	1.59 ^{bc} ± 0.07
	5	20.10 ^{abc} ± 0.70	5.97 ^{c} ± 0.03	3.97 ^{de} ± 0.03	2.09 ^{d} ± 0.02	1.73 ^{c} ± 0.12
	6	19.40 ^{ab} ± 0.40	4.98 ^{a} ± 0.12	3.01 ^{a} ± 0.12	1.41 ^{ab} ± 0.11	1.44 ^{abc} ± 0.19
	7	20.57 ^{abc} ± 0.77	5.63 ^{bc} ± 0.20	3.85 ^{bcde} ± 0.16	1.48 ^{ab} ± 0.05	1.44 ^{abc} ± 0.09
	8	19.60 ^{ab} ± 0.40	5.30 ^{abc} ± 0.22	2.91 ^{a} ± 0.09	1.60 ^{abc} ± 0.20	1.44 ^{abc} ± 0.15
2011	1	20.41 ^{abc} ± 0.59	5.63 ^{bc} ± 0.09	3.69 ^{bcde} ± 0.11	1.72 ^{bc} ± 0.04	1.44 ^{abc} ± 0.06
	2	20.27 ^{abc} ± 0.07	5.63 ^{bc} ± 0.16	3.97 ^{de} ± 0.13	1.72 ^{bc} ± 0.04	1.44 ^{abc} ± 0.10
	3	20.33 ^{abc} ± 0.18	5.63 ^{bc} ± 0.08	3.93 ^{cde} ± 0.07	1.60 ^{abc} ± 0.10	1.44 ^{abc} ± 0.09
	4	20.62 ^{abc} ± 0.38	5.97 ^{c} ± 0.08	3.56 ^{bcde} ± 0.05	1.54 ^{abc} ± 0.06	1.33 ^{ab} ± 0.11
	5	20.22 ^{abc} ± 0.14	5.80 ^{bc} ± 0.20	3.77 ^{bcde} ± 0.08	1.84 ^{bc} ± 0.06	1.22 ^{a} ± 0.01
	6	19.77 ^{abc} ± 0.23	5.97 ^{c} ± 0.13	3.56 ^{bc} ± 0.14	1.60 ^{abc} ± 0.10	1.30 ^{ab} ± 0.01
	7	20.87 ^{abc} ± 0.14	5.97 ^{c} ± 0.08	4.05 ^{e} ± 0.05	2.12 ^{d} ± 0.12	1.73 ^{c} ± 0.03
	8	19.35 ^{a} ± 0.06	5.63 ^{bc} ± 0.13	3.65 ^{bcd} ± 0.06	1.60 ^{abc} ± 0.07	1.15 ^{a} ± 0.04
Mean for fertilisation × years	1	20.67 ^{c} ± 0.44	5.80 ^{a} ± 0.25	3.62 ^{b} ± 0.08	1.60 ^{a} ± 0.08	1.44 ^{ab} ± 0.03
	2	20.54 ^{bc} ± 0.31	5.52 ^{a} ± 0.10	3.74 ^{bc} ± 0.16	1.54 ^{a} ± 0.12	1.44 ^{ab} ± 0.05
	3	20.80 ^{c} ± 0.29	5.46 ^{a} ± 0.10	3.81 ^{bc} ± 0.09	1.48 ^{a} ± 0.09	1.51 ^{ab} ± 0.08
	4	20.71 ^{c} ± 0.19	5.80 ^{a} ± 0.11	3.68 ^{b} ±0.11	1.45 ^{a} ± 0.07	1.46 ^{ab} ± 0.09
	5	20.16 ^{abc} ± 0.29	5.89 ^{a} ± 0.10	3.87 ^{bc} ± 0.07	1.97 ^{b} ± 0.08	1.48 ^{ab} ± 0.15
	6	19.59 ^{ab} ± 0.21	5.48 ^{a} ± 0.29	3.28 ^{a} ± 0.17	1.51 ^{a} ± 0.08	1.37 ^{ab} ± 0.09
	7	20.72 ^{c} ± 0.33	5.80 ^{a} ± 0.13	3.95 ^{c} ± 0.09	1.80 ^{b} ± 0.19	1.59 ^{b} ± 0.09
	8	19.48 ^{a} ± 0.18	5.48 ^{a} ± 0.13	3.27 ^{a} ± 0.21	1.60 ^{a} ± 0.06	1.30 ^{a} ± 0.11
Mean for years	2010	20.43 ^{a} ± 0.24	5.53 ^{a} ± 0.12	3.53 ^{a} ± 0.17	1.51 ^{a} ± 0.07	1.51 ^{b} ± 0.06
	2011	20.22 ^{a} ± 0.21	5.78 ^{b} ± 0.09	3.77 ^{b} ± 0.08	1.72 ^{b} ± 0.09	1.38 ^{a} ± 0.04

± standard error of the mean (SEM)
a, *b*, *c*… - with the same letter are not significantly different ($p < 0.05$)

examined by RACHOŃ et al. (2012) and RACHOŃ and SZUMIŁO (2009). Fertilisation with a dose of 120 kg ha^{-1} nitrogen in the form of ammonium nitrate and urea applied into soil (object 5) in the first year contributed raised the phosphorus content in triticale grain by 11.52% and calcium by 41.22% in comparison to soil fertilisation with urea in a dose of 80 kg ha^{-1} (object 1). The highest content of phosphorus (4.05), calcium (2.12) and magnesium (1.73) was observed in triticale grain in the second year of its cultivation under the higher dose of nitrogen and with urea applied in the form of a spray at stage BBCH 31-32. NOGALSKA et al. (2012) found greater differentiation of nitrogen, phosphorus, potassium, calcium and magnesium uptake by spring triticale of cv. Wanad in each year of the research after application of Amofosmag 4, which ensured better assimilation of nutrients from multiple-component fertilisers. Particular attention should be paid to the high content of calcium in triticale grain of cultivar Andrus (ranging on average from 1.45 to 1.97). Its concentrations are much higher than detected by KNAPOWSKI et al. (2010), who determined 0.26 g ha^{-1} of calcium in grain from cv. Kargo spring triticale. In an experiment carried out by WOJTKOWIAK and DOMSKA (2009), cultivar Gabo grown under different fertilisation regimes was also characterised by less calcium in grain (from 0.4 to 0.6 g ha^{-1}). A high level of calcium (about 1.0 g·ha^{-1}) was found by NOGALSKA et al. (2012) in grain of cultivar Wanad cultivated on light soil, but only in the second year of triticale cultivation.

The positive effect of nitrogen fertilisation can be observed in the analysis of total protein (nitrogen x 5.7) in cereal kernels. Spring triticale grain is a good source of proteins with a favourable amino acid composition (PISULEWSKA et al. 2000). The results of our research demonstrated a growing trend caused by fertilisation applied in the experiment only in the protein content (Figure 2). Evaluation of the fertilisation effect on the grain protein content is ambiguous and results published in literature are often contradictory. DOMSKA et al. (2009) confirmed the effect of fertilisation with higher doses of nitrogen fertilisers on changes in the grain quality parameters. MAKAREWICZ et al. (2012) recorded the highest amount of total protein in winter wheat grain in objects fertilised with a dose of 10% urea solution, which was not confirmed by JARECKI et al. (2012). On the other hand, according to LESTINGI et al. (2010), a dose of 50 kg ha^{-1} is sufficient to ensure good quality of triticale grain, including a satisfying total protein content. Foliar supplementation with urea did not have a significant effect on the total protein content. ORLIK et al. (2005) report that the content of protein in objects fertilised with ammonium nitrate applied to the soil and with urea sprayed over leaves was very similar, which is why - while comparing these forms of fertilisation - it is difficult to establish which had a favourable effect on the chemical composition of grain, the difficulty that also emerged in our exper-

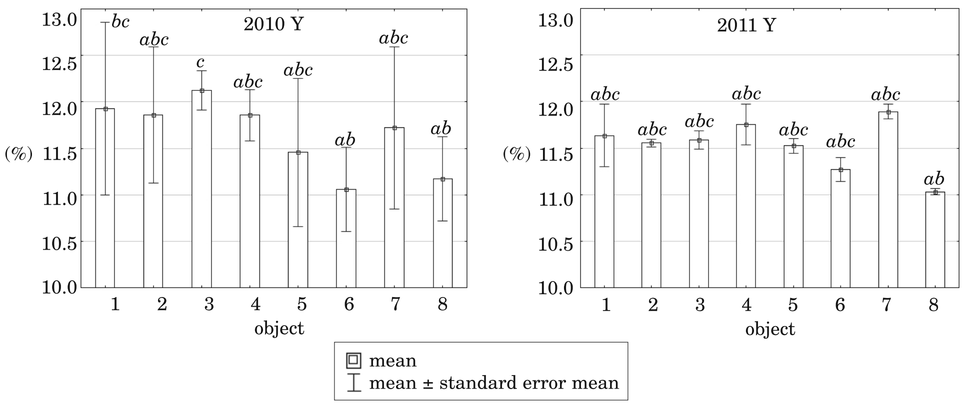

Fig. 2. Percentage content of protein (2010 and 2011 years): *a*, *b*, *c*… – with the same letter are not significantly different ($p < 0.05$)

iment. The absence of differences between the analysed fertilisation objects may stem from the genetic traits of the cultivar and from the changeable weather conditions in individual seasons. The course of weather changes not only yields of grains but also the grain protein content (Erekul, Köhn 2006). Jaskulski et al. (2011) also noted an increase in the protein content in grain under less rainfall in April and May, and more rainy June and July. Additionally, the protein concentration increased along with a decreasing calcium content, but grew as the phosphorus content increased. During our experiment, the season of 2010 was characterised by low precipitation in April and relatively high precipitation in May. The amount of protein in spring triticale grain did not increase in response to higher water supply, analogously to the research by Rakowski (2003).

An increase in the nitrogen fertilisation doses results in an increase in grain yield and in protein accumulation, but reduces grain quality (Johansson et al. 2001). Intensive fertilisation is not without significance for the protein fraction ratios. Research carried out in recent years indicates that splitting up nitrogen fertilisation into partial applications during the vegetative period and an application technique method results in changes in the protein fraction composition (Johnanson et al. 2004). The content of structural proteins (albumins and globulins) in cereal grain ranged from 21.13 to 24.01% in 2010-2011 (Table 4). The level of building protein and storage protein (glutenins) accumulation was lower in the relation to ratios of individual groups of proteins. Similar dependencies between protein fractions were found by Domska et al. (2002) in winter triticale grain from cultivar Malno. The highest percentage of the albumin and globulin fraction (24.01%) was found in the first year of cultivation under the dose 80 kg ha^{-1} nitrogen in the form of urea together with Azofoska at stage BBCH 23-29 (object 2). An increase in the nitrogen fertilisation to 120 kg ha^{-1} in the form of soil applied urea (23.47% object 5) contributed to a significant increase in albumins and globulins in triticale grain. In the second year (2011), a higher amount of structural proteins was observed in grain fertilised with 80 kg ha^{-1} nitrogen in the form of urea applied to leafage at stage BBCH 31-32 (object 3) and with the higher dose of nitrogen (120 kg ha^{-1}) applied to soil, or applied to soil and over leaves in the form of urea (object 5 and 7). The share of gliadin fraction in the examined triticale cultivar grain of was varied, being the highest in the grain from plants fertilised by the soil application of urea in a dose of 80 kg ha^{-1} (object 1), both in the first and in the second year of the experiment (56.69 and 57.93%). A 1.95% increase was caused by the higher level of fertilisation applied in the form of urea together with Azofoska at stage BBCH 23-29 (object 2 and 6) in 2010. On the other hand, in most cases (except for object 8), grain of triticale cultivated under the lower fertilisation level in the second year of contained significantly more storage protein of the gliadin fraction.

In 2010-2011, the content of storage protein of the glutenin fraction ranged from 20.65 to 24.66%. Fertilisation generally increased the share of

Table 4

True protein content (%) of grain from cv. Andrus spring triticale

Years	Object	Albumins and globulins	Gliadins	Glutenins
2010	1	$21.13^{a} \pm 0.53$	$56.69^{gh} \pm 0.43$	$22.18^{bc} \pm 0.10$
	2	$24.01^{d} \pm 0.34$	$53.26^{ab} \pm 0.80$	$22.73^{cdef} \pm 0.46$
	3	$23.08^{bcd} \pm 1.55$	$54.08^{bcd} \pm 0.78$	$22.84^{cdef} \pm 0.77$
	4	$22.92^{bcd} \pm 0.05$	$53.28^{ab} \pm 0.14$	$23.79^{fg} \pm 0.09$
	5	$23.47^{cd} \pm 0.09$	$53.69^{bc} \pm 0.14$	$22.84^{cdef} \pm 0.05$
	6	$22.20^{abc} \pm 0.13$	$54.30^{bcde} \pm 0.29$	$23.50^{def} \pm 0.43$
	7	$22.79^{abcd} \pm 0.71$	$54.24^{bcde} \pm 0.12$	$22.97^{cdef} \pm 0.59$
	8	$23.04^{bcd} \pm 0.70$	$52.30^{a} \pm 0.69$	$24.66^{g} \pm 0.01$
2011	1	$21.43^{ab} \pm 0.13$	$57.93^{h} \pm 0.39$	$20.65^{a} \pm 0.52$
	2	$21.99^{abc} \pm 0.32$	$55.63^{efg} \pm 0.61$	$22.38^{bcd} \pm 0.30$
	3	$22.30^{abcd} \pm 0.04$	$56.37^{fg} \pm 0.34$	$21.34^{ab} \pm 0.38$
	4	$22.22^{abc} \pm 0.05$	$55.25^{def} \pm 0.04$	$22.52^{bcde} \pm 0.01$
	5	$22.55^{abcd} \pm 0.05$	$55.35^{defg} \pm 0.34$	$22.10^{bc} \pm 0.38$
	6	$22.44^{abcd} \pm 0.30$	$53.91^{bcd} \pm 0.23$	$23.65^{efg} \pm 0.07$
	7	$22.80^{abcd} \pm 0.13$	$54.76^{cde} \pm 0.01$	$22.45^{bcde} \pm 0.14$
	8	$21.97^{ab} \pm 0.13$	$55.36^{defg} \pm 0.23$	$22.67^{cdef} \pm 0.10$
Average for fertilisation × years	1	$21.28^{a} \pm 0.24$	$57.31^{c} \pm 0.43$	$21.42^{a} \pm 0.49$
	2	$23.00^{b} \pm 0.61$	$54.44^{ab} \pm 0.80$	$22.56^{bc} \pm 0.24$
	3	$22.69^{b} \pm 0.67$	$55.22^{b} \pm 0.75$	$22.09^{ab} \pm 0.56$
	4	$22.57^{b} \pm 0.20$	$54.27^{ab} \pm 0.57$	$23.16^{cd} \pm 0.37$
	5	$23.01^{b} \pm 0.27$	$54.52^{ab} \pm 0.50$	$22.47^{bc} \pm 0.27$
	6	$22.32^{ab} \pm 0.15$	$54.11^{a} \pm 0.19$	$23.57^{d} \pm 0.18$
	7	$22.79^{b} \pm 0.30$	$54.50^{ab} \pm 0.16$	$22.71^{bc} \pm 0.29$
	8	$22.50^{b} \pm 0.42$	$53.83^{a} \pm 0.93$	$23.66^{d} \pm 0.58$
Average for years	2010	$22.83^{b} \pm 0.17$	$53.98^{a} \pm 0.41$	$23.19^{b} \pm 0.33$
	2011	$22.21^{a} \pm 0.22$	$55.57^{b} \pm 0.29$	$22.22^{a} \pm 0.50$

± standard error of the mean (SEM)
a, *b*, *c*… - with the same letter are not significantly different ($p < 0.05$)

this protein when a higher dose of nitrogen was applied, both in the first and in the second year of cultivation. A higher accumulation of the glutenin fraction (24.66 and 23.79%) was observed in response to the fertilisation with nitrogen as urea and ammonium nitrate together with Ekolist at stage BBCH 31-32 (object 4 and 8) in the first year and fafter the application of urea together with Azofoska at stage BBCH 23-29 in the first and the second year of cultivation (23.50% and 23.65, object 6). According to Domska and Raczkowski (2009), fertilisation of Maja cultivar spring triticale with micronutrients results in an increased share of one fraction of storage proteins, prolamins or glutenins. However, Konopka et al. (2007) demonstrated that the accumulation of individual fractions of proteins in wheat grain was largely affected by water shortage. Under water stress conditions, the accumulation of albumins, globulins, γ-gliadins and glutenins decreased. The content of gliadins and glutenins is important in the protein composition of grains used in the baking industry. The above proteins play a key role in securing unique rheological properties of wheat grain dough, and their variable concentrations depend on the genotype, growth conditions and technological processes (WIESER 2007).

The specific effect of nitrogen fertilisation on quantitative and qualitative changes in the composition of glutamin protein fraction in triticale grain remains unknown. As shown by several studies (DOMSKA et al. 2002, BARCZAK, KNAPOWSKI 2008), fertilisation with nitrogen is conductive to an increase in the content of gliadin storage proteins in various cereal species. Although the technological quality of grain improves, the content of toxic α/β gliadins can also rise (Figure 3). Proper cultivation techniques may lead to obtaining grain with a lower content of harmful gliadin fractions – gluten

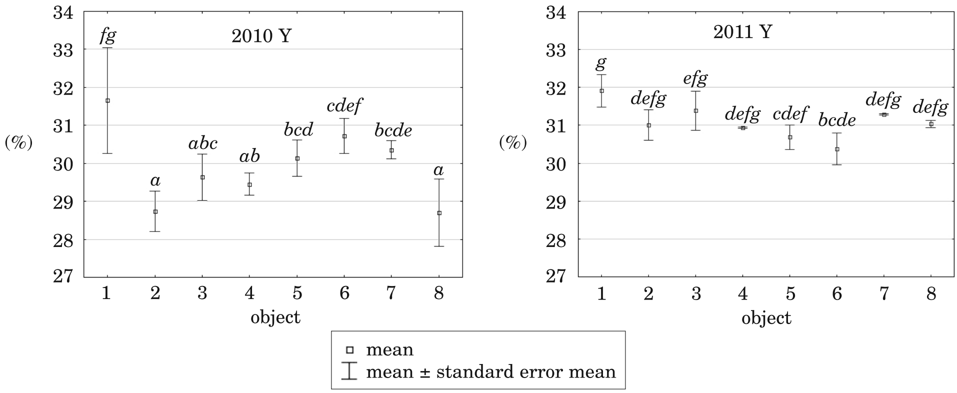

Fig. 3. Percentage part of α and β gliadins in total protein content in grain from cv. Andrus spring triticale (2010 and 2011): *a*, *b*, *c*… – with the same letter are not significantly different ($p < 0.05$)

fractions. In the present experiment, the content of α/β gliadin fractions ranged from 28.71 to 31.66% of the protein content in the first year of cultivation and from 30.38 to 31.92% in the subsequent year. Soil application off 80 kg ha^{-1} nitrogen in the form of urea contributed to the highest accumulation of this protein fraction in the context of the two years of the field experiment. An increase in fertilisation from 80 to 120 kg ha^{-1}, applied to soil as urea together with Azofoska at stage BBCH 23-29 contributed to a significant growth of this protein fraction (object 6) only in the first year of cultivation.

CONCLUSIONS

1. Differences in the experimental results on concentrations of macronutrients and protein content were caused by differences of habitat conditions in the two examined seasons.

2. A higher content of phosphorus, calcium and total protein was found in the grain of triticale fertilised with a dose of 120 kg ha^{-1} nitrogen in the form of ammonium nitrate and urea applied to soil and on leaves.

3. The accumulation of glutenins in triticale grain usually rose in response to higher doses of nitrogen (120 kg ha^{-1}), applied with and without multi-component fertilisers.

4. The introduction of foliar supplementation of urea and micronutrients in multi-component fertilisers contributed to reduced accumulation of α and β gliadins regardless of the nitrogen dose.

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