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ORIGINAL PAPER

Influence of compound fertilisers and their doses on organic components and crude ash content in two spring triticale cultivars*

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Abstract

The research material consisted of spring triticale harvested in a three-year field experiment carried out in 2017-2019 at Borki-Wyrki, Zbuczyn commune. The objective of the study was to evaluate organic composition and crude ash content in the grain of two spring triticale cultivars, with a focus on the impact of different mineral fertilisers (conventional compound fertilisers versus silicon-enriched fertilisers) and NPK-S application doses. The following three experimental factors were examined: the main factor was spring triticale cultivar (Milewo, Doublet), the sub-plot factor was mineral fertiliser type (conventional compound fertiliser 6% N, 8.7% P, 24.9% K, 2.8% S, silicon-containing fertiliser 6% N, 5.2% P, 28.2% K, 4% S, 0.5% Si), and the sub-sub-plot factor was mineral fertiliser dose (0, 140, 280, 420 kg ha^{-1}). Compound (macronutrient) solid inorganic fertilisers were used. Organic components and ash content in spring triticale grain dry matter were significantly affected by study years, cultivars and fertiliser doses. Total protein content was higher in the grain of cv. Milewo compared with Dublet, and crude fat content was greater in the grain of cv. Dublet than in cv. Milewo. Increasing fertiliser application doses were followed by an increase in the spring triticale grain content of total protein. Regardless of experimental factors, grain crude contents of fibre and crude ash were similar. Analysis of the content of organic components and ash in the dry matter of spring triticale cultivars revealed no significant effect of fertiliser type on grain quality. Fertilisation with a conventional compound fertiliser (Polifoska 6) and a silicon-containing compound fertiliser (Polifoska Krzem) supplemented with nitrogen fertiliser positively affects organic components (mainly total protein) and ash content in spring triticale grain.

Keywords: total protein, crude fat, crude fibre, crude ash

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INTRODUCTION

Triticale, a hybrid including part of Secale and Triticum genomes, has the potential to be a high-quality crop (Ammar et al. 2004, Glamočlija et al. 2018). The cereal is often cultivated in Poland because its soil requirements are lower. As there is much less research carried out into triticale compared with wheat, more studies are required to further our understanding of the crop. The chemical and nutritional composition of triticale kernels is between that of wheat and rye grains (Fan Zhu 2018, Camerlengo, Kiszonas 2023). Compared to rye protein, this species inherited a higher value protein from wheat (Boros 2002, Tikhnenko 2002, Chelkowski, Tyrka 2003) although it is quite poor in crude fibre (Glamočlija et al. 2018). Carbohydrates include mainly starch, which is an energy source, and its content in triticale grain is 50-85% (Różewicz 2019). This range is so wide due to the impact of various factors, including weather conditions during the growing season, cultivar and cultivation technology. Numerous studies have shown a significant impact of habitat conditions, including meteorological factors, on the quality of cereal grains (Ścigalska 2006, Kraska and Pałys 2009, Dekić et al. 2014, Gill and Omokanye 2016, Zutter et al. 2023). Kołodziejczyk et al. (2009) claim that less rainfall and high temperatures during the growing season cause substantial accumulation of protein in grain compared with weather conditions with more rainfall and lower temperatures. The opposite trend develops for fat because yields of agricultural crops harvested in cooler and more humid regions usually contain less fat (Górecki, Grzesiuk 2002). In the studies by Wieser and Seilmeier (1998) and Alaru et al. (2003), the quality of cereal grain was found to be mainly affected by cultivars and, to a lesser extent, by the weather conditions during the growing season. Also, the quality was shown to primarily depend on the genetic properties of a given cultivar in addition to habitat conditions and agronomic factors (Shewry 2007, Wieser 2007, Pattison, Trethowan 2013, Stępień, Wojtkowiak 2013, Wojtkowiak et al. 2014).

Many researchers have claimed that triticale grain quality is largely determined by agrotechnological factors (Gamayunova et al. 2021), of which mineral fertilisation, in particular with nitrogen, has a large impact (Johansson et al. 2001, Mut et al. 2005, Spychaj-Fabisiak et al. 2005, Lestingi et al. 2010, Hospodarenko, Liubych 2021). Nitrogen application increases the protein content in plants and fills the seeds well. In the study by Jaroszewska et al. (2016), the grain of triticale crop amended with the highest nitrogen dose (120 kg N ha^{-1}) had the highest ash and protein contents whereas the digestible nitrogen-free extract content decreased with increasing N doses of the nutrients which are components of fertilisers, it is not only nitrogen but also potassium and phosphorus that have significant influence on the qualitative characteristics of plants. Triticale takes up potassium and phosphorus at very early stages of development. A deficiency of these elements leads to poorer crop quality. In the study by Gulmezoglu and Aytac (2010), no significant differences in the grain content of total protein were found between triticale cultivars, but differences did occur at different levels of agricultural technology involving different nitrogen application doses. The concentration of many components, in particular total protein, can be influenced by fertiliser applications (Triboi, Triboi-Blondel 2002). Similarly, in the studies by Werechowska et al. (2004) and Knapowski et al. (2010), higher protein yield was obtained with higher nitrogen fertiliser inputs. Knapowski et al.(2010) reported that protein content in grain remained unaffected by fertilisation with potassium. Stępień and Mercik (2001), Kruczek and Sulewska (2005) and Nogalska et al. (2010) claim that single-nutrient fertilisers, compared to compound fertilisers, improve the nutrient uptake by various plant species.

After mixing with the topsoil, silicon used in solid fertiliser contributes to water retention, reduces temperature fluctuations and accumulates nutrients in the root zone. Introduced into deeper soil layers, it retains water, which can be released for plants during drought. Despite its high content in soil, silicon is largely inaccessible to plants. Silicon is an element which impregnates outer epidermal cells by creating a layer linked to cellular cellulose, which markedly strengthens cell walls. As a result, plants display improved resistance to adverse environmental conditions, are much healthier, and their transpiration is less intense, while the biomass production is enhanced (Starek et al. 2006). In his work, Brogowski (2000) reported that silicon fertiliser applied in rice cultivation contributed to 12-15% lower transpiration, whereas the drop in transpiration by wheat was about 10%. It should also be pointed out that silicon is an important element in human and animal nutrition (Edwardson et al. 1993, Sacała, Durbajło 2012). In recent years, droughts during the growing seasons have caused significant losses for crop farmers. It seems reasonable to use fertilisers that tend to relieve abiotic stresses. Both the type and dose of conventional compound mineral fertiliser and silicon-enriched fertiliser could enhance the grain quality of spring triticale cultivars, even in less favourable conditions during the crop growing season. Cultivar-related differences in organic components and ash content are due to genetic factors. Fertiliser type alleviates biotic and abiotic stresses (in particular drought). Increasing nitrogen doses tend to affect the total protein content in spring triticale grain.

The objective of the study reported here was to evaluate the organic composition and crude ash content in the grain of two spring triticale cultivars, with the focus on the impact of different mineral fertilisers (conventional compound fertilisers versus silicon-enriched compound fertilisers) and varying NPK-S doses. Polifoska Silicon fertiliser is a new compound product, which therefore needs more knowledge and comparison with other fertiliser often used in the cultivation of cereals in Poland. The content of organic components will vary in spring triticale cultivars depending on the doses of fertilizers used.

MATERIALS AND METHODS

In order to achieve the assumed research aim, a field experiment with spring triticale was carried out in the years 2017-2019. The experiment was run in the village Borki-Wyrki, Zbuczyn municipality, Siedlce district. The trial was set up on podzolic soil with the grain-size composition of medium clay (BN-78/9180-11). According to the FAO WRB, this soil is classified as an Albic Podzol (Ochric). The soil was characterised by high phosphorus content and average potassium and magnesium content. A split-split-plot experimental design with three replicates was used, and the plot sizes were as follows: gross area 18 m^2 and harvested area 15 m^2. In the consecutive years, the sowing dates were as follows: 8 April 2017, 10 April 2018 and 30 March 2019. The seed amounts sown corresponded to a density of 450 seeds per m^2. Multivariate analysis of variance with complete randomisation was used for calculations. Three experimental factors were investigated in the field experiment: the main factor was spring triticale cultivar (Milewo, Dublet), the sub-plot factor was mineral fertiliser type (conventional compound fertiliser Polifoska 6, silicon-containing fertiliser Polifoska Krzem), and the sub-sub-plot factor was mineral fertiliser dose (0, 140, 280, 420 kg ha^{-1}). Compound (macronutrient) solid inorganic fertilisers were used. Polifoska 6 contains 6% total nitrogen (N), 20% total phosphorus pentoxide (P_2O_5) (=8.7% P), 30% water soluble potassium oxide (K_2O) (=24.9% K), and 7% water soluble sulphur trioxide (SO_3) (=2.8% S). The product's ingredients were as follows: potassium chloride, monoammonium phosphate and ammonium sulphate. Polifoska Krzem contains 6% total nitrogen (N), 12% total phosphorus pentoxide (P_2O_5) (=5.2% P), 34% water soluble potassium oxide (K_2O) (=28.2% K), 10% water soluble sulphur trioxide (SO_3) (=4% S), and 1% total silicone dioxide (SiO_2) (=0.5% Si). The product's ingredients were potassium chloride, monoammonium phosphate and ammonium sulphate. A dose of 0 kg ha^{-1} of Polifoska 6/Polifoska Krzem was accompanied by 40 kg N ha^{-1} as ammonium nitrate (34%). Furthermore, within this treatment, an additional amount of 40 kg N ha^{-1} was applied as topdressing at BBCH 31, amounting to a total nitrogen dose (both soil and topdressing applications) of 80 kg ha^{-1}. Spring triticale cultivars recommended for cultivation in the Mazowieckie voivodship were used in the research. Cv. Milewo was bred by Strzelce Plant Breeding Ltd. IHAR Group Poland. It is a fairly tall cultivar (about 114 cm) with medium resistance to lodging. It has a medium ear formation time, and it matures quite early. Its 1000 grain weight (about 40.6 g) is at an average level with moisture content of 14%. The grain has average resistance to sprouting in the ear and an average falling number. The protein content is considered low and the productivity has been determined as very good under both moderate and high level of agricultural technology. Cv. Dublet was bred at DANKO Hodowla Roślin Sp. z o.o. in Chorynia. It is a medium height cultivar (about 109 cm) with relatively low resistance to lodging. The cultivar has a medium ear formation and maturing time. The 1000 grain weight is quite high (about 41.9 g) and the moisture content is 14%. The grain has average resistance to sprouting in the ear, an average falling number and average protein content. Its productivity is considered very good under an average agricultural technology level. It is the most popular spring triticale cultivar in Europe. Fertiliser doses were adjusted to soil fertility, taking into account the methodology of integrated plant production. Each year before sowing soil samples were collected in order to determine the grain-size composition, pH, and phosphorus, potassium and magnesium available forms. Each year, oat was the preceding crop. After its harvest, post-harvest tillage operations were carried out. In late October, pre-winter ploughing was performed to a depth of 30 cm, and the soil was left in sharp ridges, which enabled the formation of lumpy soil structure. The experimental nitrogen regime was supplemented with one dose of 40 kg N ha^{-1} before sowing followed by another 40 kg N ha^{-1} as top dressing at the first node stage (BBCH 31), each time as ammonium nitrate (34%). Weeds and pests were controlled with herbicide and insecticide. In the spring, phosphorus and potassium fertilisation was carried out in line with the methodological assumptions (Table 1). Triticale was harvested

Table 1

Fertiliser doses used in the cultivation of spring triticale

Cultivar	Fertiliser type	Fertiliser component	Fertiliser rate		
			140 (kg ha^{-1})	280 (kg ha^{-1})	420 (kg ha^{-1})
Milewo/ Dublet	conventional compound fertiliser – Polifoska 6	N	8.4 kg	16.8 kg	25.2 kg
		P_2O_5	28.0 kg	56.0 kg	84.0 kg
		K_2O	42.0 kg	84.0 kg	126.0 kg
		SO_3	9.8 kg	19.6 kg	29.4 kg
	Silicon-containing fertiliser – Polifoska Krzem	N	8.4 kg	16.8 kg	25.2 kg
		P_2O_5	16.8 kg	33.6 kg	50.4 kg
		K_2O	47.6 kg	95.2 kg	142.8 kg
		SO_3	14.0 kg	28.0 kg	42.0 kg
		SiO_2	1.4 kg	2.8 kg	4.2 kg

Note: the table does not contain basic fertilisation as it was not a factor tested in the field experiment

at the stage of full grain maturity (BBCH 89) on the following dates: 7 August 2017, 5 August 2018 and 29 July 2019. In the field experiment, a compound fertiliser called Polifoska Krzem was used. This is a new silicon-containing product. This fertiliser requires more research in the cultivation of cereals. The other product selected for comparison, Polifoska 6 is a popular fertilizer in Poland.

In each study year, representative samples of spring triticale grain were taken from each plot to determine organic components and ash content.

In the grain samples, the following components were determined: total nitrogen content – after wet mineralisation of the samples using the Kjeldahl method, followed by calculation of the total protein content computed as the product of the nitrogen content and the coefficient of 6.25 (PN-A-04018), crude fat – by Soxhlet method, crude fibre – using the Henneberg-Stohman method (for this purpose samples were boiled in diluted solutions of sulphuric acid and sodium hydroxide (PN-76/R-64814)), crude ash – by burning samples in a muffle furnace at a temp. of 600°C until grey-white ash was obtained, and then the percentage of ash in relation to the sample weight was calculated (PN-76/R-64795), and digestible nitrogen-free extract (DNFE), which was calculated by subtracting total protein, crude fat, crude fibre and crude ash from 100%.

Statistical analysis

The data obtained were analysed statistically using variance analysis according to the split-split-plot mathematical model, which was performed separately for each study year and then as synthesis across three years. The analysis of experimental data across years made use of a fixed model in the complete randomisation design. The Tukey half-confidence intervals were calculated at the significance level of $p<0.05$ to determine significant differences between means. All the calculations were made in Statistica 13.5.

Weather conditions

The distribution of temperatures and precipitation in the study years varied, as shown in the figures below (Figures 1-2), which present weather conditions, average ten-day and monthly air temperatures as well as ten-day

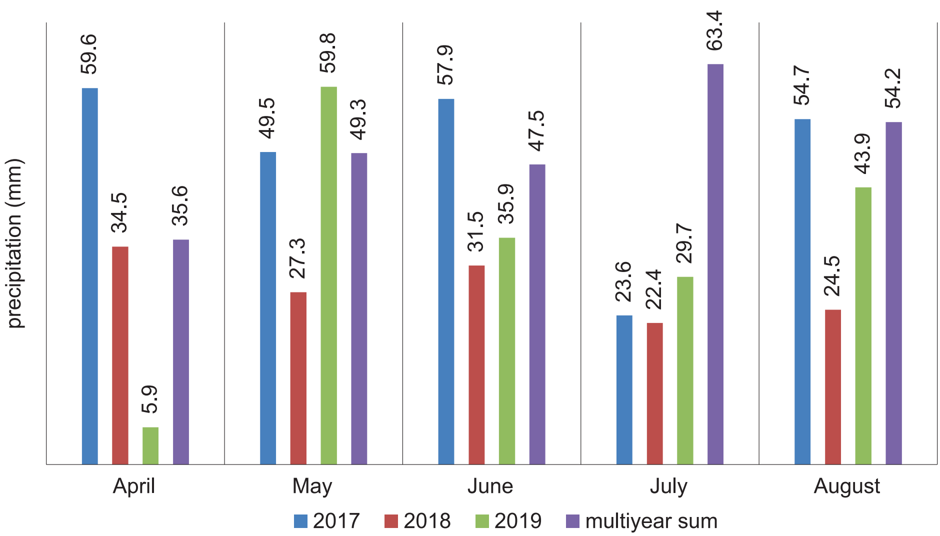

Fig. 1. Mean precipitation in study years versus the mean multiyear precipitation

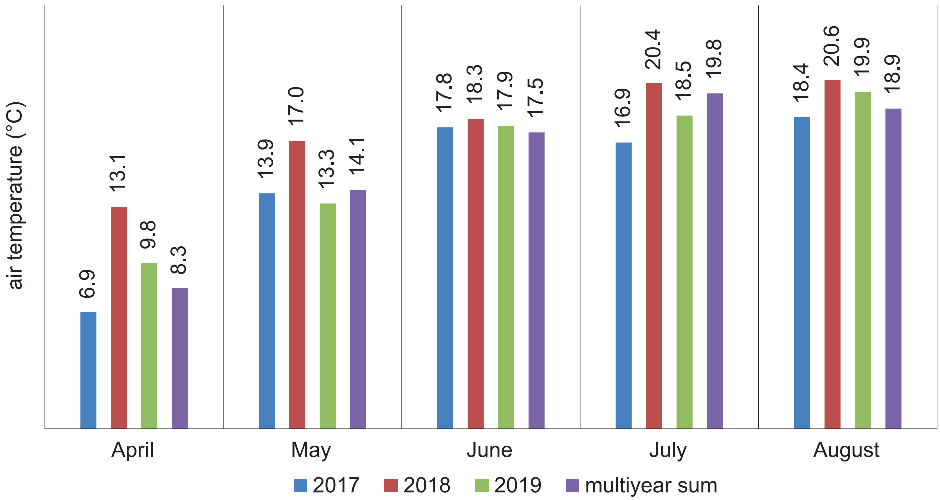

Fig. 2. Mean air temperature in study years versus the mean multiyear temperature

and monthly precipitation sums of the growing season across the study years 2017-2019. The most favourable year for the cultivation of spring triticale was 2017, when the highest amount of rainfall was recorded. Worse weather conditions prevailed in 2018, with lower precipitation and average air temperature higher than the long-term average. The highest precipitation deficit was recorded in 2018. The average air temperature oscillated around the long-term average.

RESULTS AND DISCUSSION

Table 2 shows significance of variation sources in the synthesis of 3 experimental factors across 3 study years for 5 grain quality characteristics.

Variance analysis of the results averaged across study years confirmed a significant effect of cultivars and fertiliser application doses on the accumulation of total protein (Tables 3 and 4). Higher spring triticale grain content of total protein was found in cv. Milewo than in cv. Dublet (Table 3). The highest total protein content was associated with the highest fertiliser dose, i.e. 420 kg ha^{-1}, and it was significantly higher than in the unfertilised control grain or plots amended with a dose of 140 kg ha^{-1} (Table 4). Total protein in grain increased with increasing fertiliser doses. The growing season's conditions significantly affected the total protein content in spring triticale grain. The weather conditions which were more conducive to the accumulation of total protein in grain prevailed in 2018 and 2019, when similar values were recorded, whereas the value obtained in 2017 was significantly different (Table 5). The study reported here confirmed a significant

Table 2

Significance of variation sources in the synthesis of 3 experimental factors across 3 study years for 5 grain quality traits

Source of variation	Traits (g kg^{-1} d.m.)				
	total protein content	crude fat content	crude fibre content	crude ash content	digestible nitrogen-free extract
Years (Y)	**	*	*	*	*
Culivars (C)	*	*	n.s.	n.s.	n.s.
Fertiliser types (T)	n.s.	n.s.	n.s.	n.s.	n.s.
Fertiliser rates (R)	*	n.s.	n.s.	n.s.	n.s.
T x C	n.s.	n.s.	n.s.	n.s.	n.s.
R x C	n.s.	n.s.	n.s.	n.s.	n.s.
R x T	n.s.	n.s.	n.s.	n.s.	n.s.
Y x C	n.s.	n.s.	n.s.	n.s.	n.s.
Y x T	n.s.	n.s.	n.s.	n.s.	n.s.
Y x R	n.s.	n.s.	n.s.	n.s.	n.s.
C x T x R	n.s.	n.s.	n.s.	n.s.	n.s.
Y x C x T x R	n.s.	n.s.	n.s.	n.s.	n.s.

* significant, ** highly significant, n.s. – non-significant

Table 3

Effect of cultivars on quality traits (g kg^{-1} d.m.), average values across 3 years

Traits	Cultivars		$LSD_{0.05}$
	Milewo	Dublet	
Total protein content	135.58±12.87	131.67±16.74	3.28
Crude fat content	10.37±1.21	11.49±1.19	0.92
Crude fibre content	28.26±2.16	28.51±1.86	n.s.
Crude ash content	22.35±0.62	22.29±0.35	n.s.
Digestible nitrogen-free extract	67.58±1.32	67.53±1.70	n.s

± standard deviation, n.s. – non-significant

Table 4

Effect of fertiliser doses on quality traits (g kg^{-1} d.m.), average values across 3 years

Traits	Fertiliser doses (kg ha^{-1})				$LSD_{0.05}$
	0	140	280	420	
Total protein content	128.99±15.43	131.40±14.68	136.55±15.60	137.57±14.03	5.55
Crude fat content	10.98±1.55	11.15±1.55	10.84±1.01	10.73±1.19	n.s.
Crude fibre content	27.55±2.82	28.21±1.93	29.07±1.23	28.60±1.58	n.s.
Crude ash content	22.16±0.49	22.04±0.44	22.63±0.32	22.45±0.53	n.s.
Digestible nitrogen-free extract	67.78±1.80	67.95±1.38	67.45±1.49	67.29±1.46	n.s.

± standard deviation, n.s. – non-significant

Table 5

Effect of years on quality traits (g kg^{-1} d.m.), average values across 3 years

Traits	Years			$LSD_{0.05}$
	2017	2018	2019	
Total protein content	114.83±6.22	143.44±8.42	142.62±4.54	5.03
Crude fat content	11.04±1.39	9.93±0.90	11.81±0.87	1.42
Crude fibre content	27.64±1.62	27.34±1.81	30.35±0.86	1.76
Crude ash content	22.58±0.44	22.07±0.56	22.31±0.37	0.40
Digestible nitrogen-free extract	69.35±0.63	66.87±0.92	66.60±0.84	1.01

± standard deviation, n.s. – non-significant

effect of the weather conditions, cultivars and fertiliser rates on protein content in spring triticale grain, the fertiliser being Polifoska 6 – a conventional compound product and Polifoska Krzem – a silicon-enriched formulation. Triticale inherited higher protein content compared with rye (Boros 2002, Tikhnenko et al. 2002, Chelkowski, Tyrka 2003). In the research reported here, in 2017-2019, protein content in spring triticale grain averaged 114.83-143.44 g kg^{-1} d.m. Many authors have reported that protein content in spring triticale grain is 116 g kg^{-1} d.m., on average (Różewicz, 2019). In the study by Boros (2002), the total protein content in spring triticale grain was 125 g kg^{-1} d.m but Fraś et al. (2016) reported the range of 118-152 g kg^{-1} d.m. (depending on the variety). The research by Gill and Omokanye (2016), Pattison et al. 2014 and Sirat et al. 2022 showed that meteorological factors have a significant impact on the chemical composition of cereal grain. In the present work, the total protein content in spring triticale grain was significantly lower in 2017 than in 2018 and 2019, which was caused by weather conditions during the growing seasons. In 2017, precipitation was much higher than in 2018 and 2019, when drought occurred, which positively affected the accumulation of protein in spring triticale grain. In the present study, drought stress during the stage of late grain fill limited carbohydrate incorporation in the grain and caused earlier maturation and poorer dilution of protein in the grain. This finding is consistent with the results provided by Kołodziejczyk et al. (2009), who found that less rain and high temperatures during the growing season contributed to greater accumulation of protein compared to weather conditions characterised by higher rainfall and lower temperatures. Cultivars also affected the total protein content in spring triticale grain. Cv. Milewo contained 3% more total protein than cv. Doublet. The test cultivars were obtained from two different sources. As described by their producers, cv. Milewo has an average 1000 grain weight and low total protein content, and cv. Dublet has a high 1000 grain weight and average total protein content. In the research reported here, cv. Milewo had a lower 1000 grain weight than cv. Dublet (46.9 vs 49.6 g). Total protein content displays a relatively strong negative correlation with grain size – the larger grains, the lower total protein content in spring triticale grain. To a great extent, the quality properties of triticale are determined by the genetic factor, that is the cultivar (Akgun, Altindal 2015). In the study by Gulmezoglu and Aytac (2010), no significant differences in the triticale grain content of total protein between cultivars were found, but such differences *did* occur at different agrotechnology levels, when different nitrogen fertilisation doses were applied. In the research reported here, an increase in the total protein content in spring triticale grain followed an increase in a fertiliser dose, which was due to an increased nitrogen amount, this finding being consistent with the research results reported by Warechowska et al. (2004) and Knapowski et al. (2010). Fertiliser application doses significantly affected the total protein content in spring triticale grain. Nitrogen in Polifoska 6 and Polifoska Krzem is a nutrient which significantly affects the protein content in cereal grain. An increase was observed in spring triticale grain content of the total protein following increasing fertiliser application doses. Ammonium nitrogen taken up is assimilated in the root and becomes part of amino acids, which are transported through the xylem to the leaves, and become incorporated into proteins. The seed protein of cereals comprises many different proteins, which are synthesised and accumulated in the endosperm during seed development. The total amount of protein produced depends heavily on nitrogen availability. N fertilisation is believed to promote the formation of protein aggregates (Jańczak-Pieniążek 2023). As reported by Langó et al. (2017), triticale grain shows substantial cultivar differences in protein, fat, and fibre contents. The nutritional value of different triticale genotypes indicates that they can be used not only for feeds and also in food products (Jańczak-Pieniążek 2023).

The variance analysis of the results averaged across study years revealed a significant impact of cultivars on the crude fat content in spring triticale grain (Table 3). Cv. Dublet had significantly higher fat content in grain compared with cv. Milewo. The growing season's conditions significantly affected the crude fat content in spring triticale grain. The highest amount was determined in the grain of spring triticale harvested in 2019, being significantly different from values recorded in 2018 but with no significant differences when compared with 2017 (Table 5). The weather conditions in 2018 were not conducive to the accumulation of crude fat in triticale grain, which was the result of rainfall shortages: May and June were very dry months whereas July was extremely dry. Also, average temperatures in the subsequent months of the growing season were higher than the long-term mean. The weather conditions and cultivar affected the crude fat content in spring triticale grain, the lowest values being obtained in 2018 and the highest in 2019. Crude fat ranged from 9.93 to 11.81 g kg^{-1} d.m. in the study years. The fat content in spring triticale is 8-19.8 g kg^{-1} d.m. (Startek et al. 2006). A study by Boros (2002) has shown that the crude fat content in spring triticale grain is 22 g kg^{-1} d.m. According to Górecki and Grzesiuk (2002), the crude fat content in agricultural plants shows an opposite trend to total protein. Crop plants grown in cooler and wetter regions contain less fat.

It is difficult to find such a relationship in the present work. The crude fat content was influenced by the cultivar factor, namely cv. Dublet had a fat content which was higher by 10% than determined in cv. Milewo. The study by Alijošius (2016) has confirmed that the crude fat content is predominantly dependent on the genotype.

The experimental factors had no significant effect on crude fibre and ash in spring triticale grain (Tables 3, 4, 6). However, the conditions of the growing seasons significantly influenced the accumulation of these components in spring triticale grain. The highest crude fibre content in spring triticale grain was found in 2019, and it was significantly different from the values determined in 2017 and 2018 (Table 5). The highest amount of crude ash was found in the grain of spring triticale harvested in 2017, differences being significant compared with 2018 and 2019. The crude fibre content in spring triticale ranged from 27.34 to 30.35 g kg^{-1} d.m. Triticale is quite low in crude fibre (Glamočlija et al. 2018), whose content in cereal grain is 31 g kg^{-1} d.m. (Edwardson et al. 1993).

Table 6

Effect of fertiliser types on quality traits (g kg^{-1} d.m.), average values across 3 years

Traits	Fertiliser types		$LSD_{0.05}$
	Polifoska 6	Polifoska Krzem	
Total protein content	132.48±15.51	134.78±14.52	n.s.
Crude fat content	10.72±1.45	11.14±1.15	n.s.
Crude fibre content	28.07±2.17	28.70±1.77	n.s.
Crude ash content	22.23±0.53	22.41±0.46	n.s.
Digestible nitrogen-free extract	67.60±1.68	67.65±1.34	n.s.

± standard deviation, n.s. – non-significant

Crude ash in spring triticale grain was 22 g kg^{-1} d.m. on average According to USDA/ARS (2012), the ash content in spring triticale grain is 20 g kg^{-1} d.m., whereas in the study by Boros (2002) it amounted to 21 g kg^{-1} d.m. In the experiment reported here, the ash content was the highest in 2018, when the growing season included a severe drought event.

In the years 2018-2019, no impact of the experimental factors, i.e. cultivar, fertiliser type and regime, was found on the digestible nitrogen-free extract content in spring triticale grain (Tables 3, 4, 6), which in turn was significantly affected by weather conditions in the growing seasons. The highest spring triticale grain content of DNFE was recorded in 2017, but no significant differences were found between 2018 and 2019 (Table 5). DNFE in spring triticale grain in 2017-2019 was influenced by the weather conditions and, in 2017, by the experimental factors, i.e. cultivar and fertiliser type and dose. Such wide discrepancy in the content of this compound is due to the influence of meteorological conditions. In the years 2008-2013, a study was conducted at three different locations (COBORU Cultivar Assessment

Stations) to analyse the chemical composition of grain of nine spring triticale cultivars (Boros 2002). In the present work, the DNFE content in spring triticale grain was found to range from 67.29 to 67.95 g kg^{-1} d.m., being lower in 2018 and 2019, which was due to a higher total protein content boosted by favourable weather conditions. In the current research, there was a decrease in the DNFE content in spring triticale grain following an increase in the fertiliser dose, which is consistent with the findings by Jaroszewska et al. (2016). The accumulation of carbohydrates or lipids in seeds is a manifestation of various strategies to preserve the viability of seeds and increase the chance of seeds developing into healthy plants.

In the present study, no significant difference was confirmed between the amount of organic components and ash in the grain of spring triticale fertilised with a conventional multinutrient product (Polifoska 6) and silicon-enriched product (Polifoska Krzem). Despite this, there was a beneficial effect of the latter fertiliser, mainly on grain yield (Rzążewska, Gąsiorowska 2023). Silicon positively influences crop plants, particularly during periods of biotic or abiotic stresses. In the experiment reported here, plants were subjected to a strong abiotic stress of water deficit in 2018-2019. The crops which tend to positively respond to silicon fertiliser application include monocotyledons, such as rice (*Oryza sativa*), wheat (*Triticum aestivum*), maize (*Zea mays*), barley (*Hordeum vulgare*), millet (*Panicum miliaceum* L.), sorghum (*Sorgo bicolor* L.) and sugar cane (*Saccharum officinarum* L.).

CONCLUSIONS

Organic components and ash content in the dry matter of spring triticale grain were significantly affected by the weather conditions in the study years. The total protein and crude fat content depended on the cultivars. The total protein also depended on fertiliser application doses. More total protein was found in cv. Milewo grain than in cv. Dublet, whereas the opposite was observed for crude fat. An increasing fertiliser application dose was followed by an increase in the spring triticale grain content of total protein, but no such impact being confirmed for crude fat. Regardless of the experimental factors, crude fibre and crude ash contents in triticale grain were at similar levels. Our analysis of organic components and ash content in the dry matter of the spring triticale cultivars demonstrated no significant effect of fertiliser type on grain quality.

Adequate fertiliser application doses increase the total protein content in spring triticale grain, which is important for composing concentrate feeds for animals.

No significant differences were found between Polifoska 6 and Polifoska Krzem multinutrient fertilisers in terms of their impact on the content of organic components and ash in grain. In the future, it will be worth assessing the impact of a liquid formulation of silicon-containing fertiliser.

Author contributions

Conceptualization, methodology, software, formal analysis, investigation, resources, data curation, writing – original draft preparation, writing – review and editing, visualization, supervision – E.Rz. I agreed to the published version of the manuscript.

Conflicts of interest

The author declare no conflict of interest.

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