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YIELD COMPONENTS OF SPRING TRITICALE AS AFFECTED BY CULTIVAR AND MULTI-NUTRIENT FERTILISER TYPE AND RATE

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Abstract. A field experiment was conducted throughout the years 2017–2019 at Borki-Wyrki, Zbuczyn *Gmina* (commune). The study aimed at determining productive ear number, grain number per ear, grain weight per ear and 1000 grain weight of two spring triticale cultivars according to fertiliser type and rate, the fertiliser being either Polifoska 6 or Polifoska Krzem. The following three experimental factors were investigated in the experiment: the main factor – spring triticale cultivar (Milewo, Dublet), the sub-plot factor – mineral fertiliser type (Polifoska 6, Polifoska Krzem), the sub-sub-plot factor – mineral fertiliser rate (0 kg·ha^{-1}, 140 kg·ha^{-1}, 280 kg·ha^{-1}, 420 kg·ha^{-1}). Fertiliser rates increased productive ear number compared to unfertilised control. Fertiliser type significantly affected grain number per ear. An application of Polifoska Krzem was followed by increased grain number per ear in spring triticale. Grain weight per one ear was significantly affected cultivars. Cv. Milewo had a higher number of grains per ear compared with cv. Dublet. Spring triticale grain harvested from units fertilised with Polifoska 6 had a higher 1000 grain weight. Cv. Dublet developed more robust grain compared with cv. Milewo.

Key words: productive ear number, grain number per ear, grain weight per ear, 1000 grain weight.

INTRODUCTION

Apart from weather and soil-related conditions, cultivar and agrotechnological practices such as fertilisation exert the greatest influence on cereal plant yield levels (Budzyński and Szempliński 2003; Giunta and Motzo 2004; Starczewski and Czarnocki 2004). Numerous soil analyses conducted all over Poland in recent years have revealed substantial shortages of macroelements. As a result, is seems fully warranted to apply multi-nutrient fertilisers, such as Polifoska 6, as they enrich the soil with both macro- and microelements. Producers of fertilisers also offer new multi-nutrient products which need to be studied to understand their effect on crop plant yielding. Such fertilisers include a less examined multi-nutrient product called Polifoska Krzem. Triticale yield components are to a large extent determined by agrotechnological factors such as mineral

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fertilisation, in particular nitrogen application. Nitrogen fertilisation stimulates tiller formation by plants, which leads to higher ear numbers per unit area (Jaśkiewicz 2002; Podolska et. al 2002). Grain yield is the result of an interplay of ear number per unit area, grain number per ear and 1000 grain weight. Higher nitrogen fertiliser inputs result in better side shoot survival and thus higher numbers of ears (Podolska 2008). According to Lipa (2004), lower mineral fertiliser rates may result in poorer elements of cereal yield architecture and yield, in particular ear number per unit area and 1000 grain weight. Unfortunately, spring triticale cultivars are characterised by poor tillering even when they are supplied with optimum nitrogen amounts (Jaśkiewicz 2015). Fertilisation with phosphorus and potassium is of importance in agricultural plant cultivation. Research into cereal crops by Piwowar (2013) has demonstrated that phosphorus tends to increase grain number per ear as well as 1000 grain weight. In recent years, increasing attention has been paid to silicon as the element which plays an important role in crop plant agrotechnology. The physiological importance of silicon is associated with an enhanced plant resistance to diseases and pests, which results in improved components of cereal plant yielding. The study by Yu and Gao (2012) has revealed that an application of appropriate silicon-containing fertilisers tends to increase ear number and grain number per ear. The aim of the study was to evaluate the grain yield components of two cultivar of spring triticale depending on the type of mineral fertiliser and doses, using a multi-nutrient fertiliser in the form of Polifoska 6 and Polifoska Silicon. Both the type and doses of mineral fertiliser in the form of Polifoska 6 and Polifoska Silicon will contribute to the proper growth and development of plants.

MATERIALS AND METHODS

In order to accomplish the assumed research objectives, a field study with spring triticale was carried out during three consecutive growing seasons (2017–2019). The trial was set up at Borki-Wyrki which is situated in Zbuczyn Gmina, Siedlce Poviat. The experiment was conducted on the soil representing the podzol type whose granulometric composition was that of a medium loam soil (BN-78/9180-11). The WRB FAO classifies the soil as representing Albic Podzols (Ochric) whereas according to the international USDA classification, which takes into account the soil's granulometry, it is categorised as a sandy clay loan. The soil was characterised by a high phosphorus content, and average potassium and magnesium contents. A split-split-plot experimental design was used with three replicates and the following plot sizes: gross area 18 m^2 and the harvested area 15 m^2. 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 (Polifoska 6, Polifoska Krzem), and the sub-sub-plot factor was mineral fertiliser rate (0 $kg \cdot ha^{-1}$, 140 $kg \cdot ha^{-1}$, 280 $kg \cdot ha^{-1}$, 420 $kg \cdot ha^{-1}$), in Table 2 shows doses of fertilizers used in the cultivation of spring triticale. The Milewo variety was bred in the Plant Breeding Plant Strzelce Sp. z o. o. IHAR group. It was entered into the National Register in 2008. It is a fairly tall variety (about 114 cm) with medium resistance to lodging. The time of earing of this variety is medium, and ripening is quite early. The weight of 1000 grains is at an average level, with a moisture content of 14% it is about 40.6 g. The grain has an average resistance to sprouting in the ear and an average falling number. It has an average tolerance to soil acidity (COBORU 2016). The Doublet variety was bred at DANKO Plant Sp. z o. o. in Chorynia. It was entered into the National Register in 2006. It is a variety with medium plant height (about 109 cm) and quite low resistance to lodging. The time of earing and ripening is medium. The weight of 1000 grains is quite large, with a moisture content of 14% it is about 41.9 g. Tolerance to soil acidification is quite low. It is the most widely cultivated variety of spring triticale in Europe (COBORU 2016).Throughout the three study years oats was the crop preceding spring triticale. Spring applications of phosphorus and potassium fertilisers were made according to the methodological assumptions. Additional preplant and post-plant nitrogen fertiliser applications of, respectively, 40 and 40 kg·ha^{-1} were made, each time using ammonium nitrate (34%) at the first node stage (BBCH 31) of spring triticale. Weeds and pests were controlled using herbicide and insecticide applications. In the following years of research, the sowing dates were as follows: April 8, 2017, April 10, 2018 and March 30, 2019. The number of seeds sown corresponded to a planting density of 450 plants/m^2. Triticale was harvested at the stage of full grain maturity (BBCH 98). Triticale was harvested in the study years: August 7, 2017, August 5, 2018 and July 29, 2019, respectively. The obtained data was 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. Separation of means was achieved by means of Tukey test at the significance level of $p = 0.05$. Thermal and moisture conditions throughout the growing seasons of the study years were analysed using the Sielianinov's hydrothermal coefficient (K).

Table 1. Sielianinov's hydrothermal coefficient (K) values in individual months of spring triticale growing seasons

Year	Month				
	April	May	June	July	August
2017	2.85 (vw)	1.13 (qd)	1.08 (qd)	0.45 (vd)	0.99 (d)
2018	0.88 (qw)	0.52 (vd)	0.57 (vd)	0.35 (ed)	0.40 (ed)
2019	0.20 (ed)	1.45 (o)	0.66 (vd)	0.53 (vd)	0.73 (d)

Table 2. Doses of fertilizers used in the cultivation of spring triticale

Cultivar	Fertiliser type	Fertiliser component	Fertiliser rate			
			0 kg·ha^{-1}	140 kg·ha^{-1}	280 kg·ha^{-1}	420 kg·ha^{-1}
Milewo	Polifoska 6	N	0 kg	8.4 kg	16.8 kg	25.2 kg
		P_2O_5	0 kg	28.0 kg	56.0 kg	84.0 kg
		K_2O	0 kg	42.0 kg	84.0 kg	126.0 kg
		SO_3	0 kg	9.8 kg	19.6 kg	29.4 kg
	Polifoska Silicon	N	0 kg	8.4 kg	16.8 kg	25.2 kg
		P_2O_5	0 kg	16.8 kg	33.6 kg	50.4 kg
		K_2O	0 kg	47.6 kg	95.2 kg	142.8 kg
		SO_3	0 kg	14.0 kg	28.0 kg	42.0 kg
		SiO_2	0 kg	1.4 kg	2.8 kg	4.2 kg
Dublet	Polifoska 6	N	0 kg	8.4 kg	16.8 kg	25.2 kg
		P_2O_5	0 kg	28.0 kg	56.0 kg	84.0 kg
		K_2O	0 kg	42.0 kg	84.0 kg	126.0 kg
		SO_3	0 kg	9.8 kg	19.6 kg	29.4 kg
	Polifoska Silicon	N	0 kg	8.4 kg	16.8 kg	25.2 kg
		P_2O_5	0 kg	16.8 kg	33.6 kg	50.4 kg
		K_2O	0 kg	47.6 kg	95.2 kg	142.8 kg
		SO_3	0 kg	14.0 kg	28.0 kg	42.0 kg
		SiO_2	0 kg	1.4 kg	2.8 kg	4.2 kg

An assessment of the hydrothermal conditions prevailing in a given year was based on values of coefficient K divided into 10 classes (Skowera i Puła 2004): $K \leq 0.4$ extremely dry (ed); $0.4 < K \leq 0.7$ very dry (vd); $0.7 < K \leq 1.0$ dry (d); $1.0 < K \leq 1.3$ quite dry (qd); $1.3 < K \leq 1.6$

optimum (o); 1.6 < K ≤ 2.0 quite wet (qw); 2.0 < K ≤ 2.5 wet (w); 2.5 < K ≤ 3.0 very wet (vw); K > 3.0 extremely wet (ew).

Based on the Sielaninov's coefficient, the first month in the 2017 and 2018 growing seasons, that is April, was found to be wet whereas the consecutive months that followed were very dry, quite dry, dry and extremely dry (Table 1). As a whole, the growing season in 2017 was more favourable compared to 2018. Favourable moisture conditions in both 2017 and 2018 occurred in April. The months of May and June were quite dry in the first study year and very dry in the second study year, which resulted in negative conditions for plant growth and development. Values of hydrothermal coefficient indicated that the months of July and August in the 2017 growing season were, respectively, very dry and dry, both being extremely dry in 2018. The beginning of the growing season in 2019 was extremely dry, too, and was followed by a favourable precipitation distribution in May which was classified as optimum based on the Sielianinov's coefficient. Substantial rainfall shortages were recorded in the months that followed, them being very dry and dry, which negatively affected spring triticale grain filling.

RESULTS

Variance analysis of results averaged across study years revealed a significant effect of fertiliser rate. Productive ear number in spring triticale was the lowest in the control unit without fertiliser application (Table 2). Fertiliser applied at the rate of 140 $kg \cdot ha^{-1}$ contributed to a significant increase in productive ear number in spring triticale. When the rate was further increased to the level of 280 and 420 $kg \cdot ha^{-1}$, there was observed a significant rise in the number of productive ears in spring triticale compared with control. Growing season conditions significantly affected productive ear number in spring triticale. The most favourable weather conditions for spring triticale growth and development were observed in 2017, and they resulted in the greatest number of productive ears in spring triticale. Less conductive weather conditions were recorded in the 2018 growing season, and they resulted in a significant decline in the number of productive ears in spring triticale compared to 2017. In the 2019 growing season, productive ear numbers were significantly lower compared with 2017 although it was still significantly higher than in 2018. Based on variance analysis of the study results, study years were found to interact with fertiliser rates. In 2017, a significant difference was found between plots receiving fertiliser inputs and unfertilised control. In 2019, a significant difference in the number of productive ears was confirmed between the fertiliser input of 280 or 420 $kg \cdot ha^{-1}$ and the unfertilised control unit.

Variance analysis of results averaged across study years demonstrated a significant influence of fertiliser type on grain number per one ear of spring triticale (Table 3). Greater numbers of grains per ear were obtained following an application of Polifoska Krzem versus Polifoska 6. Growing season conditions significantly affected grain number per one ear of spring triticale, too. The most favourable weather conditions for the growth and development of spring triticale plants were recorded throughout the 2017 growing season when the greatest numbers of grains were developed per ear. Less favourable weather conditions with lower precipitation levels were recorded for the 2018 growing season, which resulted in significantly lower number of grains per ear compared to 2017 and 2019. Variance analysis of study results revealed significant differences in grain number per ear between the study years. There was confirmed an interaction of years and cultivars, which is indicative of the fact that both cv. Milewo and Dublet had the highest number of grains per ear in the 2017 growing season followed by 2019 and 2018. There was also confirmed an interaction of years and fertiliser type which indicated that spring triticale grain number per ear was significantly higher in the growing season of 2018 and 2019 when Polifoska Krzem was applied, and in 2017 when Polifoska 6 was used.

Table 2. Productive ear number of test spring triticale cultivars (C) affected by fertiliser type (T) and rate (R) [ear number per·m²]

Study years	Cultivar	Fertiliser type	Fertiliser rate in kg·ha⁻¹ 0	140	280	420	Mean
2017	Milewo	Polifoska 6	197	210	204	214	206
		Polifoska Krzem	181	214	234	218	212
		mean	189	212	219	216	209
	Dublet	Polifoska 6	186	193	199	201	195
		Polifoska Krzem	190	217	218	210	209
		mean	188	205	209	206	202
	mean	Polifoska 6	191	201	201	208	200
		Polifoska Krzem	185	216	226	214	210
		mean	188	208	214	211	205
	$LSD_{0.05}$ for:		C – non significant (ns.); T – ns.; R – 14.83; TxC – ns.; RxC – ns.; RxT – ns.				
2018	Milewo	Polifoska 6	179	177	183	181	180
		Polifoska Krzem	176	178	178	180	178
		mean	177	178	180	180	179
	Dublet	Polifoska 6	175	177	174	174	175
		Polifoska Krzem	178	172	177	179	177
		mean	177	174	176	177	176
	mean	Polifoska 6	177	177	179	177	178
		Polifoska Krzem	177	175	177	180	177
		mean	177	176	178	179	177
	$LSD_{0.05}$ for:		C – ns.; T – ns.; R – ns.; TxC – ns.; RxC – ns.; RxT – ns.				
2019	Milewo	Polifoska 6	182	189	201	196	192
		Polifoska Krzem	183	191	200	200	194
		mean	183	190	201	198	193
	Dublet	Polifoska 6	188	197	200	195	195
		Polifoska Krzem	185	194	204	200	196
		mean	186	196	202	198	195
	mean	Polifoska 6	185	193	201	196	194
		Polifoska Krzem	184	193	202	200	195
		mean	184	193	201	198	194
	$LSD_{0.05}$ for:		C – ns; T – ns.; R – 5.43; TxC – ns.; RxC – ns.; RxT – ns.				
2017–2019	Milewo	Polifoska 6	186	192	196	197	193
		Polifoska Krzem	180	194	204	199	194
		mean	183	193	200	198	194
	Dublet	Polifoska 6	183	189	191	190	188
		Polifoska Krzem	184	194	200	197	194
		mean	184	192	195	193	191
	mean	Polifoska 6	185	190	194	194	191
		Polifoska Krzem	182	194	202	198	194
		mean	183	192	198	196	192
	$LSD_{0.05}$ for:		C – ns.; T – ns.; R – 5.34; TxC – ns.; RxC – ns.; RxT – ns.; Y – 4.38; YxC – ns.; YxT – ns.; YxR – 8.43				

Table 3. Grain number per ear of test spring triticale cultivars (C) affected by fertiliser type (T) and rate (R)

Study years	Cultivar	Fertiliser type	Fertiliser rate in kg·ha⁻¹				Mean
			0	140	280	420	
2017	Milewo	Polifoska 6	40.6	47.6	44.6	44.4	44.3
		Polifoska Krzem	45.8	43.4	45.3	43.0	44.4
		mean	43.2	45.5	45.0	43.7	44.3
	Dublet	Polifoska 6	46.4	47.5	47.3	46.6	47.0
		Polifoska Krzem	44.7	43.9	45.1	45.6	44.8
		mean	45.6	45.7	46.2	46.1	45.9
	mean	Polifoska 6	43.5	47.6	46.0	45.5	45.6
		Polifoska Krzem	45.3	43.7	45.2	44.3	44.6
		mean	44.4	45.6	45.6	44.9	45.1
	$LSD_{0.05}$ for:		C – ns.; T – ns.; R – ns.; TxC – ns.; RxC – ns.; RxT – ns.				
2018	Milewo	Polifoska 6	31.6	35.4	30.9	33.0	32.7
		Polifoska Krzem	39.6	38.7	34.4	34.7	36.9
		mean	35.6	37.1	32.7	33.8	34.8
	Dublet	Polifoska 6	24.2	26.8	31.1	32.1	28.6
		Polifoska Krzem	28.8	36.0	34.4	31.6	32.7
		mean	26.5	31.4	32.8	31.8	30.6
	mean	Polifoska 6	27.9	31.1	31.0	32.5	30.6
		Polifoska Krzem	34.2	37.4	34.4	33.1	34.8
		mean	31.1	34.2	32.7	32.8	32.7
	$LSD_{0.05}$ for:		C – 2.93; T – 1.02; R – ns.; TxC – ns.; RxC – 4.71; RxT – ns.				
2019	Milewo	Polifoska 6	33.1	30.7	41.6	41.9	36.8
		Polifoska Krzem	38.6	42.3	42.1	40.1	40.8
		mean	35.8	36.5	41.9	41.0	38.8
	Dublet	Polifoska 6	41.6	36.4	31.4	39.9	37.3
		Polifoska Krzem	39.4	38.3	39.4	41.4	39.6
		mean	40.5	37.4	35.4	40.7	38.5
	mean	Polifoska 6	37.4	33.6	36.5	40.9	37.1
		Polifoska Krzem	39.0	40.3	40.8	40.8	40.2
		mean	38.2	36.9	38.6	40.8	38.6
	$LSD_{0.05}$ for:		C – ns.; T – 0.47; R – 3.33; TxC – 1.01; RxC – 4.71; RxT – ns.				
2017–2019	Milewo	Polifoska 6	35.1	37.9	39.1	39.8	38.0
		Polifoska Krzem	41.3	41.5	40.6	39.2	40.7
		mean	38.2	39.7	39.8	39.5	39.3
	Dublet	Polifoska 6	37.4	36.9	36.6	39.5	37.6
		Polifoska Krzem	37.7	39.4	39.6	39.5	39.1
		mean	37.5	38.2	38.1	39.5	38.3
	mean	Polifoska 6	36.3	37.4	37.8	39.6	37.8
		Polifoska Krzem	39.5	40.4	40.1	39.4	39.9
		mean	37.9	38.9	39.0	39.5	38.8
	$LSD_{0.05}$ for:		C – ns.; T – 0.63; R – ns.; TxC – ns.; RxC – ns.; RxT – ns.; Y – 1.40; YxC – 1.98; YxT – 1.09; YxR – ns .				

In the 2017 and 2019 study years, experimental factors, that is cultivar, fertiliser type and fertiliser rate, had an insignificant effect on grain weight per ear in spring triticale (Table 4). Mean results calculated across study years demonstrated a significant effect of cultivar and fertiliser type on grain weight per ear. A higher grain weight per spring triticale ear was confirmed for cv. Dublet. Significantly the greatest grain weight per ear was recorded following fertilisation with 420 kg·ha⁻1, it being the lowest for unfertilised control plants. Growing season conditions throughout the years 2017–2019 significantly affected grain weight per ear in spring triticale. The lowest grain weight per ear was obtained in the 2017 growing season when a lower precipitation sum was recorded in July, the greatest grain weight per ear being found for the 2018 growing season when July received the greatest amount of precipitation. Significant differences in grain weight per ear were confirmed between the growing seasons under study.

Table 4. Grain weight per ear of test spring triticale cultivars (C) affected by fertiliser type (T) and rate (R) [g]

Study years	Cultivar	Fertiliser type	Fertiliser rate in kg·ha^{-1}				Mean
			0	140	280	420	
2017	Milewo	Polifoska 6	1.9	1.9	1.9	2.1	2.0
		Polifoska Krzem	1.8	1.9	2.0	2.0	1.9
		mean	1.9	1.9	1.9	2.0	1.9
	Dublet	Polifoska 6	2.2	2.3	2.2	2.2	2.2
		Polifoska Krzem	2.1	2.0	2.1	2.1	2.1
		mean	2.1	2.1	2.2	2.2	2.1
	mean	Polifoska 6	2.1	2.1	2.1	2.1	2.1
		Polifoska Krzem	1.9	2.0	2.1	2.0	2.0
		mean	2.0	2.0	2.1	2.1	2.0
	$LSD_{0.05}$ for:		C – ns.; T – ns.; R – ns.; TxC – ns.; RxC – ns.; RxT – ns.				
2018	Milewo	Polifoska 6	2.0	2.3	2.2	2.3	2.2
		Polifoska Krzem	2.0	2.3	2.5	2.5	2.3
		mean	2.0	2.3	2.4	2.4	2.3
	Dublet	Polifoska 6	2.3	2.4	2.5	2.5	2.5
		Polifoska Krzem	2.2	2.5	2.6	2.5	2.5
		mean	2.3	2.5	2.6	2.5	2.5
	mean	Polifoska 6	2.2	2.4	2.4	2.4	2.3
		Polifoska Krzem	2.1	2.4	2.6	2.5	2.4
		mean	2.1	2.4	2.5	2.5	2.4
	$LSD_{0.05}$ for:		C – ns.; T – ns.; R – 0.18; TxC – ns.; RxC – ns.; RxT – ns.				
2019	Milewo	Polifoska 6	1.9	2.2	2.0	2.2	2.1
		Polifoska Krzem	1.9	2.1	2.2	2.2	2.1
		mean	1.9	2.1	2.1	2.2	2.1
	Dublet	Polifoska 6	2.2	2.2	2.2	2.2	2.2
		Polifoska Krzem	2.2	2.2	2.3	2.2	2.2
		mean	2.2	2.2	2.2	2.2	2.2
	mean	Polifoska 6	2.0	2.2	2.1	2.2	2.1
		Polifoska Krzem	2.0	2.2	2.3	2.2	2.2
		mean	2.0	2.2	2.2	2.2	2.2
	$LSD_{0.05}$ for:		C – ns.; T – ns.; R – ns.; TxC – ns.; RxC – ns.; RxT – ns.				
2017–2019	Milewo	Polifoska 6	1.9	2.1	2.0	2.2	2.1
		Polifoska Krzem	1.9	2.1	2.2	2.2	2.1
		mean	1.9	2.1	2.1	2.2	2.1
	Dublet	Polifoska 6	2.2	2.3	2.3	2.3	2.3
		Polifoska Krzem	2.2	2.2	2.3	2.3	2.3
		mean	2.2	2.3	2.3	2.3	2.3
	mean	Polifoska 6	2.1	2.2	2.2	2.3	2.2
		Polifoska Krzem	2.0	2.2	2.3	2.3	2.2
		mean	2.1	2.2	2.2	2.3	2.2
	$LSD_{0.05}$ for:		C – 0.12; T – ns; R – 0.09; TxC – ns.; RxC – ns.; RxT – ns.; Y – 0.15; YxC – ns.; YxT – ns.; YxR – ns.				

Table 5. 1000 grain weight of test spring triticale cultivars (O) affected by fertiliser type (R) and rate (D) [g]

Study years	Cultivar	Fertiliser type	Fertiliser rate in kg·ha^{-1}				Mean
			0	140	280	420	
2017	Milewo	Polifoska 6	43.9	41.1	44.1	44.4	43.4
		Polifoska Krzem	42.3	43.2	44.4	44.4	43.6
		mean	43.1	42.1	44.2	44.4	43.5
	Dublet	Polifoska 6	47.5	47.2	46.4	47.2	47.1
		Polifoska Krzem	46.8	45.5	47.2	46.3	46.5
		mean	47.2	46.4	46.8	46.8	46.8
	mean	Polifoska 6	45.7	44.1	45.3	45.8	45.2
		Polifoska Krzem	44.6	44.4	45.8	45.4	45.0
		mean	45.1	44.2	45.5	45.6	45.1
	$LSD_{0.05}$ for:		C – ns.; T – ns.; R – ns.; TxC – ns.; RxC – ns.; RxT – ns.				
2018	Milewo	Polifoska 6	51.1	52.0	50.8	50.3	51.0
		Polifoska Krzem	46.7	48.9	48.4	50.5	48.6
		mean	48.9	50.5	49.6	50.4	49.8
	Dublet	Polifoska 6	51.1	52.0	50.8	50.3	51.0
		Polifoska Krzem	46.7	48.9	48.4	50.5	48.6
		mean	48.9	50.5	49.6	50.4	49.8
	mean	Polifoska 6	51.1	52.0	50.8	50.3	51.0
		Polifoska Krzem	46.7	48.9	48.4	50.5	48.6
		mean	48.9	50.5	49.6	50.4	49.8
	$LSD_{0.05}$ for:		C – ns.; T – 1.72; R – s.; TxC – ns.; RxC – ns.; RxT – ns.				
2019	Milewo	Polifoska 6	48.0	55.3	44.7	41.5	47.4
		Polifoska Krzem	45.0	46.1	48.1	51.2	47.6
		mean	46.5	50.7	46.4	46.4	47.5
	Dublet	Polifoska 6	46.2	54.6	60.4	52.4	53.4
		Polifoska Krzem	47.4	53.2	53.3	50.4	51.1
		mean	46.8	53.9	56.9	51.4	52.2
	mean	Polifoska 6	47.1	55.0	52.6	47.0	50.4
		Polifoska Krzem	46.2	49.7	50.7	50.8	49.4
		mean	46.7	52.3	51.6	48.9	49.9
	$LSD_{0.05}$ for:		C– 0.64; T – 0.65; R – 1.49; TxC – 1.40; RxC – 2.11; RxT – 2.11				
2017–2019	Milewo	Polifoska 6	47.7	49.5	46.5	45.4	47.3
		Polifoska Krzem	44.7	46.1	47.0	48.7	46.6
		mean	46.2	47.8	46.7	47.1	46.9
	Dublet	Polifoska 6	48.3	51.3	52.5	50.0	50.5
		Polifoska Krzem	47.0	49.2	49.6	49.1	48.7
		mean	47.6	50.2	51.1	49.5	49.6
	mean	Polifoska 6	48.0	50.4	49.5	47.7	48.9
		Polifoska Krzem	45.8	47.6	48.3	48.9	47.7
		mean	46.9	49.0	48.9	48.3	48.3
	$LSD_{0.05}$ for:		C – 0.80; T – 0.62; R – 1.43; TxC – ns.; RxC – ns.; RxT – 1.55; Y – 0.98; YxC – 1.38; YxT – 1.07; YxR – 2.06				

Variance analysis of results averaged across study years demonstrated a significant effect of cultivars, fertiliser type and fertiliser rate (Table 5). A higher 1000 grain weight was recorded for cv. Dublet compared with cv. Milewo. Also, higher values of 1000 grain weight were obtained following an application of Polifoska 6 vs. Polifoska Krzem. Moreover, significantly higher 1000 grain weight results were recorded for fertilised plots vs. unfertilised control. Growing season conditions significantly affected 1000 grain weight in spring triticale throughout the years 2017–2019. Significantly higher 1000 grain weight values were found for the 2018 and 2019 growing seasons compared to 2017. An interaction of years and cultivars indicated that 1000 grain weight of the test cultivars differed due to weather conditions prevailing in the growing seasons. The discussed characteristic had higher values in the 2018 and 2019 growing seasons compared with 2017, the highest 1000 grain weight for this cultivar being recorded for the 2018 growing season. For cv. Dublet, 1000 grain weight was the highest and the lowest in, respectively, the 2019 and 2017 growing season. The confirmed interaction of years and fertiliser type indicated that, in the 2018 growing season, there was a significant difference in 1000 grain weight between spring triticale plants fertilised with Polifoska 6 and Polifoska Krzem. In turn, a significant year-by-fertiliser rates interaction means that the greatest, although statistically insignificant, 1000 grain weight values for the 2017 growing season resulted from an application of 420 $kg \cdot ha^{-1}$ of fertiliser compared with unfertilised control whereas in 2018 and 2019 the highest values were due to the rate of 140 $kg \cdot ha^{-1}$, it resulting in a significant difference compared with control.

DISSCUSION

Productive ear number was significantly affected by atmospheric conditions in the years 2017–2019 as well as fertiliser rate. Growing season conditions were unfavourable for spring triticale development. Throughout the study years, atmospheric precipitation sums were much lower compared with the long-term mean, which was also not conducive to spring triticale development. There was observed substantial reduction of plant number from emergence to harvest as well as numerous non-productive ears. Plant tillering was very poor. In the research by Stankowski (1994) and Nieróbca (2004), there was observed substantial specificity of spring triticale compared with other species. In the present study, when the number of plants was 450 per 1 m^2, there was noted a substantial increase in the number of plants with one productive shoot. The number of productive ears was higher in 2017, followed by 2019 and 2018 when grain seeding was delayed compared to 2019 due to drought. Fertiliser rate significantly affected productive ear number in spring triticale, too. According to Lipa (2004), lower mineral fertilisation (particularly nitrogen) may lead to reduced ear numbers. It is well-known that an increase in Polifoska 6 or Polifoska Krzem rate is associated with an increased nitrogen fertilisation level. However, research by Jaśkiewicz (2015) has demonstrated that, in spite of optimum nitrogen rates, spring triticale cultivars display poor tillering and, as a result, they develop very low productive ear numbers. In the present work, higher numbers of productive ears were obtained following fertilisation with Polifoska Krzem vs. Polifoska 6, which was also confirmed by findings reported by Yu and Gao (2012). They claimed that silicon tended to increase productive ear numbers.

Weather conditions and fertiliser type affected grain number per one ear of spring triticale in the study reported here. The highest grain numbers per ear were recorded in 2017 which was the most conducive to spring triticale growth and development. It was significantly higher following an application of Polifoska Krzem compared with Polifoska 6. According to Piwowar (2013), phosphorus is the macroelement which tends to increase grain number per ear, and it is Polifoska 6 and not Polifoska Krzem that contains more phosphorus (20 and 12%, respectively). However, Górecki and Grzesiuk (2002) claim that the physiological importance of silicon consists in, among others, positively affecting phosphorus uptake by the root system. Hence, spring triticale fertilised with Polifoska Krzem was able to take up an adequate amount of phosphorus.

Grain weight per one ear was affected by weather conditions, cultivars and fertiliser rates. The highest grain weight per ear was obtained in the 2018 growing season, which was probably associated with the lowest number of grains per ear, as a result of which all the grains were larger and better-developed. Cv. Milewo had a lower grain weight per ear whereas grain number per ear of cv. Dublet was around 9% higher. According to Wicki and Dudek (2009), biological progress contributes to enhanced yield components. Fertiliser rate significantly affected grain number per ear in spring triticale compared with unfertilised control. Mazur et al. (2001), Stępień and Mercik (2001) as well as Zawartka and Skwierawska (2004) claim that multi-nutrient fertilisers have a positive effect on many plant species. In turn, Lipa (2004) has found that reduced mineral fertilisation may lead to reduced cereal yield structure.

1000 grain weight in spring triticale was influenced by weather conditions and all the experimental factors, that is cultivar, fertiliser type and fertiliser rate. The lowest 1000 grain weight was recorded in the first study year, explaining the highest grain number per ear. In the dry years 2018 and 2019, 1000 grain weight was much higher but grain number per ear was lower. Cv. Dublet had a higher 1000 grain weight compared with cv. Milewo. It is a cultivar-related characteristic because, as demonstrated in research by COBORU (2016), cv. Milewo and Dublet have the following 1000 grain weights: 40.6 and 41.9 g, respectively. Fertiliser type significantly affected 1000 grain weight in spring triticale. The grain of spring triticale fertilised with Polifoska 6 had a higher 1000 grain weight. It seems to follow from the fact that Polifoska 6 contains more phosphorus, which, as claimed by Piwowar (2013), gives an increase in 1000 grain weight. Also fertiliser rate affected 1000 grain weight, it being higher for spring triticale fertilised with the test rates compared with unfertilised control. This was probably due to an increased soil content of phosphorus (Piwowar 2013) which enhances yield components (Kozłowska et. al 2007).

CONCLUSIONS

1. Spring triticale yield components were significantly affected by weather conditions in the study years.
2. Fertiliser input caused an increase in productive ear number compared with unfertilised control.
3. Fertiliser type significantly affected grain number per ear. An application of Polifoska Krzem was followed by increased grain number per ear in spring triticale.
4. Cultivars significantly affected grain weight per one ear of spring triticale. Cv. Milewo was characterised by higher grain number per ear compared with cv. Dublet.
5. Spring triticale grain harvested from units fertilised with Polifoska 6 had a higher 1000 grain weight. The applied mineral fertilisation contributed to an increase in 1000 grain weight. Cv. Dublet developed more robust grain compared with cv. Milewo.

REFERENCES

Budzyński W., Szempliński W. 2003. Pszenżyto, in: Szczegółowa uprawa roślin. Eds. Z. Jasińska, A. Kotecki. Wrocław, AR Wrocław, 161 [in Polish].

COBORU. 2016. List of varieties recommended for cultivation in the Mazowieckie Voivodeship. Seroczyn, Centralny Ośrodek Badania Odmian Roślin Uprawnych, 37.

Giunta F., Motzo R. 2004. Sowing rate and cultivar effect total biomass and grain yield of spring triticale (X *Triticosecale Wittmack*) grown in a Mediterranean type environment. Field Crops Res. 87(2-3), 179–193. DOI: 10.1016/j.fcr.2003.11.009.

Górecki R., Grzesiuk S. 2002. Fizjologia plonowania roślin. Olsztyn, Wydaw. UWM [in Polish].

Jaśkiewicz B. 2002. Determination of agrotechnical requirements of new varieties of winter triticale. Bulletin. IHAR 223/224, 151–157.

Jaśkiewicz B. 2015. Pszenica czy pszenżyto jare? [Wheat or spring triticale?]. Farmer 2, 56–70 [in Polish].

Kozłowska M. 2007. Fizjologia roślin. PWRiL, Poznań, 173–186 [in Polish].

Lipa J. 2004. Nowoczesna ochrona zbóż [Modern crop protection]. Pam. Puł. 135, 241–259 [in Polish].

Mazur T., Mazut Z., Wojtas A., Grześkowiak A. 2001. Wpływ nawozów wieloskładnikowych na wielkość i jakość plonów roślin uprawnych w 4-polowym zmianowaniu [Influence of compound fertilizers on crop yield and quality in 4-field rotation]. Folia Univ. Agric. Stein. Agricultura 223(89), 113–119 [in Polish].

Nieróbca P. 2004. Wpływ nawożenia azotowego, terminu siewu i ilosci wysiewu na plon i elementy struktury plonu pszenżyta jarego [The effect of nitrogen fertilization, sowing time and sowing density on yield and yield components in the spring triticale]. Bulletin. IHAR 231, 231–235 [in Polish].

Piwowar A. 2013. Zarys problematyki nawożenia w zrównoważonym rozwoju rolnictwa w Polsce [Outline of the problem of fertilization in the sustainable development of agriculture in Poland]. Ekon. Środ. 1(44), 143–155 [in Polish].

Podolska G. 2008. Wpływ dawki i sposobu nawożenia azotem na plon i wartość technologiczną ziarna odmian pszenicy ozimej [Effect of nitrogen fertilization doses and way of its application on yield and technological quality of winter wheat cultivars grain]. Acta Sci. Pol. Agricultura 7(1), 57–65 [in Polish].

Podolska G., Sułek A., Stankowski S. 2002. Obsada kłosów – podstawowy parametr plonotwórczy pszenicy ozimej [Number of ears per area unit – main factor of winter wheat yielding (review)]. Acta Agric. 1(2), 5–14 [in Polish].

Skowera B., Puła J. 2004. Skrajne warunki pluwiotermiczne w okresie wiosennym na obszarze Polski w latach 1971–2000 [Pluviometric extreme conditions in spring season in Poland in the years 1971–2000]. Acta Agrophys. 3(1), 171–177 [in Polish].

Stankowski S. 1994. Reakcja pszenżyta jarego na termin siewu, ilość wysiewu, rozstawę rzędów i głębokość siewu w uprawie na glebie lekkiej. Szczecin, AR Szczecin, 159 [in Polish].

Starczewski J., Czarnocki S. 2004. Sposób uprawy roli a zachwaszczenie i plonowanie pszenżyta [Tillage method and triticale weed infestation and yielding]. Acta Sci. Pol. Agricultura 3(2), 69–76 [in Polish].

Stępień W., Mercik S. 2001. Działanie na rośliny i glebę nawozów wieloskładnikowych i pojedynczych w zmianowaniu pięciopolowym [The impact of mulit-component and simple fertilizers on crops and soil in five-feld rotation]. Folia Univ. Agric. Stein. Agricultura 89, 165–168 [in Polish].

Wicki L., Dudek H. 2009. Factors influencing productivity of cereals in Polish agriculture. Econ. Sci. Rural Dev. 20, 79–88.

Yu L.H., Gao J.L. 2012. Effects of silicon on yield and grain quality of wheat. J. Triticeae Crops. 32, 469–473.

Zawartka L., Skwierawska M. 2004. Wpływ nawozów wieloskładnikowych na plon i zawartość fosforu i innych makroelementów w jęczmieniu jarym [Influence of multicomponent fertilisers on the crop yield and phosphorus and other macroelements content in the Spring Barley]. Chemia 1017, 149–157 [in Polish].

KOMPONENTY PLONOWANIA PSZENŻYTA JAREGO W ZALEŻNOŚCI OD ODMIANY, RODZAJU I DAWKI NAWOZU WIELOSKŁADNIKOWEGO

Streszczenie. Doświadczenie polowe zostało przeprowadzone w latach 2017–2019 w miejscowości Borki-Wyrki na terenie gminy Zbuczyn. Celem przeprowadzonych badań było określenie liczby kłosów produkcyjnych, liczby ziaren w kłosie, masy ziaren z jednego kłosa oraz masy 1000 ziaren

2 odmian pszenżyta jarego w zależności od rodzaju i dawek nawozu, z zastosowaniem nawozu w postaci Polifoski 6 i Polifoski Krzem. W doświadczeniu uwzględniono 3 czynniki badawcze – pierwszym czynnikiem była odmiana pszenżyta jarego (Milewo, Dublet), drugim czynnikiem był rodzaj nawozu mineralnego (Polifoska 6, Polifoska Krzem), trzecim czynnikiem były dawki nawozu mineralnego (0 kg·ha^{-1}, 140 kg·ha^{-1}, 280 kg·ha^{-1}, 420 kg·ha^{-1}). Dawka nawozu powodowała zwiększenie liczby kłosów produkcyjnych w porównaniu z obiektem kontrolnym, bez nawożenia. Rodzaj nawozu modyfikował istotnie liczbę ziaren w kłosie. Stwierdzono większą liczbę ziaren w kłosie pszenżyta jarego przy stosowaniu nawozu Polifoska Krzem. Odmiana różnicowała istotnie masę ziaren z jednego kłosa. Odmiana Milewo charakteryzowała się większą liczbą ziaren w kłosie niż odmiana Dublet. Ziarno pszenżyta jarego zebrane z obiektów nawożonych Polifoską 6 charakteryzowało się większą masą 1000 ziaren. Odmiana Dublet wykształciła dorodniejsze ziarno w porównaniu z odmianą Milewo.

Słowa kluczowe: liczba kłosów produkcyjnych, liczba ziaren w kłosie, masa ziaren z kłosa, masa 1000 ziaren