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The productivity of spring wheat (*Triticum aestivum* L.) on the autumn sowing date

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Abstract. There are not many results of studies concerning the effect of autumn sowing date on the yield of spring cereal cultivars. Due to the fact that meteorological conditions in winter have become milder, the sowing of spring varieties with increased frost resistance is possible in autumn. Spring varieties suitable for autumn sowing are known as alternative varieties. The aim of the research was to determine the effect of autumn sowing date on the productivity of selected spring varieties. A two-factor field experiment was established using a split-plot design at the Experimental Station of Cultivar Testing in Czesławice (51°30′N 22°24′E), the Lubelskie voivodeship, Poland (2008/2009, 2009/2010, 2010/2011). Experimental factors were as follows: A) sowing date: I – October, II – November, III – spring, B) spring wheat cultivar: Tybalt, Cytra, Bombona, Monsun, Parabola. In the first year of the study, no effect of sowing date on spring wheat yields was found. In subsequent growing seasons, both autumn sowing dates had a positive effect on the yields of the tested spring wheat varieties. The selection of the cultivar did not affect the obtained yields.

Keywords: spring wheat, alternative wheat, yield, productivity, sowing term

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most important cultivated plants in Poland and worldwide (Ratajczyk, Michalak, 2004). In cereal cultivation around the world, one can distinguish spring forms – sown in spring and winter forms – sown in autumn, as well as transitional forms sown in both autumn and spring (Listowski, 1963). A significant difference between winter and spring genotypes is that spring plants require a higher initial temperature than winter cereals during their development (Gumiński, 1977). According to Listowski (1963), proper winter and spring wheats differ in terms of the requirements during the development stages, especially the stage of vernalization. In Poland, winter forms of this species dominate in cultivation, which is motivated by their higher yields (Jasińska, Kotecki, 2003). That is why the aim to sow as much cereal as possible in autumn is justified in Poland. However, the area of lower-yielding spring wheat is relatively small in Poland. According to the Polish Central Statistical Office (GUS), in 2015 its area amounted to 13% of the area sown with this species (GUS, 2016). One of the main reasons for the lower fertility of spring forms of cereals is their lower resistance to spring droughts, which affect most of Poland almost annually. Early sowing is less susceptible to precipitation deficiencies in spring, but in our climatic conditions, especially on heavy soils, it is not always possible to apply such a date. In recent years, there has been information from farmers that spring varieties can also be sown in autumn (Kardasz et al., 2010). Such varieties must exhibit an increased frost resistance, which allows them to withstand the harsh winter weather conditions. The autumn sowing date lengthens the growing season, allows plants to use the post-winter water reservoirs, and lets the crops avoid frequent droughts in spring. According to certain sources (Rudnicki et al., 1999; Kurowski, Bruderek, 2009; Kardasz et al., 2010), yields from such sowings are usually higher by a dozen or even several dozen percent in comparison to those that are performed in spring – at the optimal term.

Many articles in popular and scientific press indicate that a large group of agricultural producers use spring varieties for autumn sowing. A large part of the farmers decide to sow crops that are harvested later: potatoes, sugar beets, and maize. Many scientists describe spring varieties suitable for autumn sowing as "alternative varieties" (Grocholski et al., 2007; Hnilička et al., 2005; Weber, Kaus, 2007; Wenda-Piesik, Wasilewski, 2015). Spring and winter genotypes differ in terms of thermal requirements during

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the vernalization stage (Listowski, 1963). Winter wheat needs lower temperatures in this period in order to be able to produce crops later (Gumiński, 1977). As Listowski (1963) states, apart from spring and winter genotypes, there are also transitional forms useful both for sowing in autumn and spring. Such varieties are known in many countries and have their own names there. In Russia, these are 'dwurutschki', in Hungary – 'jaro', in Germany – 'die Wechselweizen' (Hnilička et al., 2005). In Yugoslavia, they are called 'intermediate' or 'dual purpose', and in France 'le ble alternative' (Hnilička et al., 2005).

The aim of the research was to determine the effect of autumn sowing date on the productivity of selected spring wheat cultivars.

MATERIAL AND METHODS

Field trials were conducted during three vegetation seasons 2008/2009, 2009/2010, and 2010/2011 at the Experimental Center for Variety Testing in Czesławice (51°30′N 22°24′E), the Lubelskie voivodeship, Poland, belonging to the Research Centre for Cultivar Testing (COBORU). The basis for the research were two-factor field experiments, in a split-plot design, with four replications. The first-order factor (A) was the sowing time: I – autumn (after 2–3 weeks later than specified in IUNG-PIB agronomical recommendations, as deliberately delayed for winter wheat), II – autumn (delayed from the first by 1–3 weeks), III – spring (indicated according to the agrotechnical guidelines of IUNG-PIB for spring wheat as the earliest possible). The sowing terms showed Table 1. The second order factor (B) was the spring wheat cultivar: Tybalt, Cytra, Bombona, Monsun, Parabola. All tested cultivars had increased frost resistance compared to the standard spring genotypes. The experiments were located on brown soil on loess, soil quality class II. The plot area was 15 m^2.

Meteorological conditions during particular growing seasons during the research are presented in Table 2. In all growing seasons, weather conditions at the time of wheat sowing, were favorable in terms of both temperature and precipitation. The most dangerous were the low temperatures in January in the 2009/2010 growing season but the plants did well. Weather conditions were also favorable for the wheat maturity.

Mineral fertilization with phosphorus and potassium was applied depending on soil nutrient contents, while nitrogen was used depending on the level of grain yields predicted. The experiment was located on Brown soil, soil quality class II. Mineral fertilization was: N – 150 $kg\,ha^{-1}$, P_2O_5 – 64 $kg\,ha^{-1}$, K_2O – 96 $kg\,ha^{-1}$. Analyses showed that the soil had a neutral pH, its value amounting to 6.8.

The seeding rate of wheat was 500 $grains\,m^{-2}$. After reaching full maturity, the final harvest was made using a combine harvester. The following values were determined: grain yield at 14% of moisture, number of plants and ears per area, productive tillering, weight of 1000 grains (TGW). Productive tillering was calculated by dividing the number of ears from 1 m^2 area by the number of plants obtained from this area. Samples were taken from 1 m^2 area, in three replications.

Table 1. Dates of spring wheat sowing in growing seasons.

Growing season	Dates of sowing I	II	III
2008/2009	24.10.2008	13.11.2008	02.04.2009
2009/2010	26.10.2009	23.11.2009	29.03.2010
2010/2011	22.10.2010	19.11.2010	02.04.2011

Table 2. Meteorological conditions in individual growing seasons.

Month	Temperature [°C]				Rainfall [mm]			
	2008/2009	2009/2010	2010/2011	long term average	2008/2009	2009/2010	2010/2011	long term average
October	9.4	7.0	4.8	8.0	75.6	89.7	11.1	46.0
November	4.0	4.8	5.8	2.9	34.3	48.6	54.6	39.0
December	0.9	-1.4	5.4	-1.3	37.0	45.8	32.5	36.0
January	-3.3	-8.3	-1.4	-3.1	22.1	41.9	35.7	31.0
February	-1.2	-2.4	-4.1	-1.8	32.2	53.3	24.1	28.0
March	1.3	2.3	2.6	2.0	57.7	21.6	15.8	32.0
April	10.2	8.8	10.2	7.9	0.0	29.0	33.9	42.0
May	12.9	13.0	13.4	13.6	72.5	116.2	53.1	62.0
June	15.8	17.5	18.5	16.5	126.1	58.4	83.5	75.0
July	19.7	20.8	18.2	18.3	54.7	84.8	160.0	83.0
August	18.4	20.0	18.5	17.7	56.2	147.1	36.7	70.0
Mean (X–VIII)	8.0	7.5	8.4	7.3	51.67	66.95	49.18	49.45

Statistical evaluation was carried out using the Statgraphics Centurion v. XVI. Analysis of variance was performed, then Tukey test was used to find the significant differences at a level of α = 0.05.

RESULTS AND DISCUSSION

In all growing seasons, the meteorological conditions, both in the autumn and spring months, were favorable for good seed germination and further plant development.

The impact of experimental factors on wheat yields was not the same over the years (Table 3). In 2009, only the genetic factor (cultivar) significantly influenced the grain yield. Cytra and Bombona varieties yielded the highest. There was also an interaction of experimental factors, which was manifested by differences in the response of varieties to the sowing date – in the first (I) and third (III) sowing dates, Cytra yielded the highest, and in the second term – Monsun. The higher grain yield from III sowing term in the first year of the study can be explained by the fact that the plants sown in spring were not affected by the drought, as the sum of rainfall in May was quite high. On the other hand, in 2010 the highest wheat yields were obtained using the first (I) sowing date, and its delay by 2–3 weeks (term II) caused a significant decrease in the grain yield (by over 1 t ha^{-1}). An even bigger yield reduction was observed in the case of the spring sowing. The difference in yields obtained on the treatments with the first (I) and third (III) sowing dates exceeded 48%. On average, the highest yield was obtained by Parabola, while the lowest by Bombona. The difference in grain yields of these varieties exceeded 10%. It should also be noted that the date of sowing influenced the yield of individual cultivars in different ways. Under October sowing conditions (term I), the highest yield was achieved by Monsun, while in second (II) and third (III) Parabola (Table 3). In the second year of the study, a considerably lower grain yield obtained from spring sowing was caused by a lower plant and ear density per area unit, which was probably influenced by the lack of available water, as both in March and April the total precipitation was lower compared to the multi-year period. In the harvest year 2011, the highest yields were obtained using November sowing (term II), while they were smaller (the difference being insignificant) for October sowing (term I). However, in the case of the spring date, the yield reduction in relation to that achieved from both autumn sowings, was very high at 1.94 and 2.24 t ha^{-1}. Differences were found in the response of varieties to the date of sowing. Under the first (I) sowing date, the highest grain yield was obtained from Tybalt variety, while under the second (II) and third (III) terms, from Parabola variety (Table 3). Lower grain yields from spring sowing should be explained by the limited availability of water for both the sown seeds and the plants after the emergence. Sums of rainfall in March, April and May were lower than those of the many-year period.

Both experimental factors had a significant impact on spring wheat grain yield. This topic was also the subject of research by other authors (Kardasz et al., 2010; Weber, Kaus, 2007). The Olimpia and Helia varieties produced higher yields at the late autumn sowing date compared to spring sowing. Zebra, Torka and Nawra responded differently. Therefore, the authors do not recommend them for

Table 3. Yield of spring wheat [t ha^{-1}] in Czesławice.

Years	Sowing term (A)#	Cultivar (B)					
		Tybalt	Cytra	Bombona	Monsun	Parabola	Mean
2009	I	4.58	5.25	5.23	4.56	4.49	4.82
	II	4.34	4.56	4.79	4.82	4.63	4.62
	III	4.96	5.34	5.12	5.03	4.52	4.99
Mean		4.63	5.05	5.04	4.80	4.54	–
$LSD_{0.05}$ for A = n.s.; B = 0.225; B/A= 0.389; Standard deviation 0.763							
2010	I	8.03	7.79	6.79	8.11	7.58	7.66
	II	6.75	5.62	6.40	6.52	7.07	6.47
	III	3.78	3.75	3.78	3.95	4.33	3.92
Mean		6.19	5.72	5.65	6.19	6.32	–
$LSD_{0.05}$ for A = 0.674; B = 0.431; B/A= 0.746; Standard deviation 1.270							
2011	I	8.67	7.05	7.62	8.19	7.83	7.87
	II	8.31	7.49	7.65	8.53	8.88	8.17
	III	5.36	4.96	6.20	6.16	6.99	5.93
Mean		7.44	6.50	7.16	7.63	7.90	–
$LSD_{0.05}$ for A = 0.088; B = 0.437; B/A = 0.757; Standard deviation 0.953							

see Table 1
n.s. – differences not significant

autumn sowing. Olimpia variety, due to its high yield instability, is also not recommended for autumn sowing. In the studies quoted, spring wheat varieties were compared against winter wheat varieties. All spring wheat varieties tested did not yield at the winter wheat level (Weber, Kaus, 2007). According to Ozturk et al. (2006), by sowing alternative varieties in the autumn, the grain yield can be increased by about 37% compared to sowing at the optimal time (spring). Also Grocholski et al. (2007) indicate that autumn spring wheat sowing yields are much higher. Research conducted by Kardasz et al. (2010) confirms the results of previous research. The increase in spring wheat grain yield was between 43.2–65.6%, depending on the cultivar. Sułek et al. (2017) also confirm the beneficial effect of the autumn sowing date on spring wheat yield. According to Ozturk et al. (2006), the spring wheat sown in the first week of September produced a higher grain yield than in spring. Also, our own research (Wyzińska, Grabiński, 2018) conducted on the same wheat varieties, indicated the usefulness of spring wheat varieties for autumn sowing. Grain yields from such sowings are significantly higher in comparison with spring sowings.

The genetic factor did not play a significant role in shaping the number of plants per area unit, whereas the role of sowing date in shaping this feature of the canopy was variable in the years (Table 4). In 2009, no influence of experimental factors on the number of plants per area unit was found, but a tendency for higher plant density was found in spring sowing treatments. In 2010, significantly more plants per area unit were found in the treatments with the second (II) sowing date, and in the next one, in spring sowing conditions. According to the research carried out by Kardasz et al. (2010), the plant density per area unit was higher in the treatments where autumn sowing was used. According to the authors, this can be explained by the fact that better-rooted plants were more resistant to water shortages. On the other hand, a study carried out in IUNG-PIB (Sułek et al., 2017) gave a smaller number of plants per area unit in autumn sowing. In our previous study (Wyzińska, Grabiński, 2018), no significant differences in the value of this trait depending on the date of sowing were found.

The number of ears per area unit was shaped by experimental factors in individual years differently (Table 5). In 2009, it did not significantly depend on the date of sowing and wheat cultivar. However, in the remaining two years, both factors and their interactions shaped the number of ears per unit area significantly. In 2010 and 2011, the highest ear density was found for the second (II) sowing term. However, in 2010 a very strong decrease in the density of ears on the treatments with the third (III) sowing term (spring) was observed, while in 2011 the lowest density of ears was observed as a result of the first (I) autumn date of sowing wheat. In 2010 the largest number of ears per unit area was formed by the Tybalt variety, in 2011 – Tybalt and Bombona while the smallest by the Cytra variety. Similar results were also obtained by Kardasz et al. (2010). Spring wheat sown in the autumn showed a higher number of ears compared to sowing in the optimal time. To a large extent, the number of ears depends on productive tillering (Wenda-Piesik, Wasilewski, 2015). Wheat sown in the autumn tillers much earlier than wheat sown in the spring, and thus the tillering stage lasts longer in comparison to wheat sown in the spring. Studies carried out on the same wheat varieties (Wyzińska, Grabiński, 2018) indicate that the number

Table 4. Number of plants per 1 m^2 in Czesławice.

Years	Sowing term (A)#	Cultivar (B)					
		Tybalt	Cytra	Bombona	Monsun	Parabola	Mean
2009	I	328	312	320	328	344	326
	II	328	224	352	360	352	323
	III	368	368	348	340	360	356
Mean		341	301	340	342	352	–
LSD $_{0.05}$ for A = n.s.; B = n.s.; B/A = n.s.; Standard deviation 12.1							
2010	I	304	304	304	308	301	304
	II	350	344	344	366	352	351
	III	296	280	256	300	272	281
Mean		316	309	301	325	308	–
LSD $_{0.05}$ for A = 47.9; B = n.s.; B/A = 42.4; Standard deviation 31.6							
2011	I	320	324	280	320	288	306
	II	320	288	304	300	228	300
	III	386	372	396	336	396	377
Mean		342	328	327	318	324	–
LSD $_{0.05}$ for A = 55.7; B = n.s.; B/A = n.s.; Standard deviation 17.9							

see Table 1
n.s. – differences not significant

Table 5. Number of ears per 1 m^2 in Czesławice.

Years	Sowing term (A)#	Cultivar (B)					
		Tybalt	Cytra	Bombona	Monsun	Parabola	Mean
2009	I	448	482	520	490	494	487
	II	472	404	496	527	520	484
	III	560	556	477	478	416	497
Mean		493	481	498	498	477	–
LSD $_{0.05}$ for A = n.s.; B = n.s.; B/A = 83.1; Standard deviation 39.1							
2010	I	576	432	424	496	362	478
	II	560	454	576	480	512	516
	III	370	282	300	453	412	363
Mean		502	389	433	476	462	–
LSD $_{0.05}$ for A = 34.1; B = 81.5; B/A = 130.5; Standard deviation 33.5							
2011	I	449	454	448	528	456	475
	II	568	428	560	596	506	532
	III	516	432	568	424	560	500
Mean		525	438	525	516	507	–
LSD $_{0.05}$ for A = 45.5; B = 60.4; B/A = 80.3; Standard deviation 15.7							

see Table 1
n.s. – differences not significant

Table 6. Productive tillering of spring wheat in Czesławice.

Years	Sowing term (A)#	Cultivar (B)					
		Tybalt	Cytra	Bombona	Monsun	Parabola	Mean
Synthesis from years 2009–2011	I	1.60	1.45	1.54	1.58	1.52	1.54
	II	1.61	1.54	1.64	1.59	1.56	1.59
	III	1.37	1.23	1.32	1.39	1.36	1.33
Mean		1.45	1.52	1.41	1.50	1.52	–
LSD $_{0.05}$ for A = 0.200; B = n.s.; B/A = n.s.; Standard deviation 0.32							

see Table 1
n.s. – differences not significant

Table 7. Thousand grain weight [g] in Czesławice.

Years	Sowing term (A)#	Cultivar (B)					
		Tybalt	Cytra	Bombona	Monsun	Parabola	Mean
Synthesis from years 2009–2011	I	33.72	39.40	36.57	34.38	41.46	37.11
	II	33.78	37.47	36.48	38.15	42.63	37.70
	III	31.88	32.13	36.98	34.43	39.03	34.89
Mean		33.13	36.36	36.68	35.65	41.04	–
LSD $_{0.05}$ for A = 2.210; B = 3.460; B/A = 4.440; Standard deviation 1.44							

see Table 1
n.s. – differences not significant

of ears per unit area in wheat sown in spring was lower in comparison to the sowings carried out on autumn dates, but the differences were not statistically significant.

In Czesławice, the effect of the sowing date and cultivar on the production tillering was similar over the years. The results show that spring sowing plants were characterized by significantly lower tillering than both autumn sowing plants (Table 6). Differences between cultivars in the scope of plant tillering were insignificant. Studies carried out in IUNG-PIB (Sułek et al., 2017) indicate that spring wheat sown in the spring term tillered better than those sown in the autumn. In our own study (Wyzińska, Grabiński, 2018), only in 2010, a significant effect of the sowing date on spring wheat productive tillering, was found.

The results of the research carried out in Czesławice showed that wheat grain from autumn sowing had a similar weight of 1000 grains, and at the same time, significantly higher than from spring sowing (Table 7). The lower 1000 grain weight from spring sowing results from low precipitation in particular years in the summer months, which constituted the period of grain formation (grain filling). In the first year of the study, compared to the long-term period, a lower sum of precipitation was recorded in July, in the second year in June. The Parabola cultivar was characterized by a significantly higher value of this trait, and the lowest by Tybalt. Many research results (Grocholski et al., 2007; Kardasz et al., 2010; Sułek et al., 2017; Wyzińska, Grabiński, 2018) indicate a higher weight of 1000 grains for autumn sowing. This is due to the fact that spring wheat sown in late autumn has a better grain development as the plants are not threatened by frequent spring droughts, and are therefore not exposed to stress.

CONCLUSIONS

1. The autumn sowing date had a positive effect on the spring wheat grain yield. Only in 2009, influence of the sowing date on the grain yield was not found. In 2010 and 2011, grain yields from autumn sowing dates were significantly higher than those obtained from spring sowing.
2. The cultivar factor did not affect the number of plants. In 2010 and 2011 the number of plants per unit area depended on the date of sowing. However, this trait was variable in years, which indicates a significant impact of weather conditions on plant density per unit area.
3. The date of sowing significantly influenced the number of ears per area unit (2010 and 2011). When sowing in the second autumn term, the value of this trait was at the highest level. In 2010 and 2011, the density of ears per area unit also depended on the genetic factor. The Tybalt cultivar had the highest number of ears per area unit in two consecutive years of the study, in 2011 also Bombona cultivar.
4. Productive tillering depended on the date of sowing. Under autumn sowing, wheat showed a significantly higher number of production shoots as compared to the plants sown in spring.
5. The experimental factors significantly shaped the weight of 1000 grains. With both sowing dates in autumn, the value of this trait was higher in relation to spring sowing. Among the studied cultivars, the highest value of this trait was found in Parabola, while the lowest in Tybalt.

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