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THE INFLUENCE OF AUTUMN SOWING DATE ON THE PRODUCTIVITY OF SPRING WHEAT (*TRITICUM AESTIVUM* L.)

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Abstract
The greatest interest in the cultivation of spring wheat is in regions with an increased intensity of late fallow. However, there are also stronger tendencies to limit the area of its cultivation (similarly to other spring cereals), which is mainly due to a lower level of yielding. Farmers decide on the sowing date of varieties mainly after plants that leave the field late, e.g., potatoes, beets and maize. That is why these varieties are usually called „alternative wheat".The aim of the research was to determine the effect of autumn sowing date on the yield and the technological value of the grains of selected spring wheat varieties. A two-factor field experiment was established using a split-plot design at the Experimental Station of Cultivar Testing (ESCT) in Bezek (51°12′06″N 23°16′06″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 variety: 'Tybalt', 'Cytra', 'Bombona', 'Monsun', 'Parabola'. It was found that grain yields of spring wheat sown in the autumn were higher than those sown in the spring term. Without regard to the sowing term, the highest grain yields were obtained from 'Tybalt' cultivar.
Key words: spring wheat, alternative wheat, yield, productivity, sowing term.

Introduction

Wheat (*Triticum aestivum* L.) is one of the most important cereal species in the world. In world production, this species ranks third after rice and maize. Great advantage of wheat cultivation results from the high level of yield, valuable chemical composition, wide possibilities of grain use for consumption purposes, in particular for the production of flour, and for baking and feed purposes. Two forms of wheat are grown in the world: winter and spring wheat (Jasińska & Kotecki, 2003). The greatest interest in the cultivation of spring wheat is in regions with an increased intensity of late fallow. However, there are also stronger tendencies of limiting the area of its cultivation (similarly to other spring cereals), which is mainly due to a lower level of yielding. The yield of spring wheat, reduced in relation to the winter form, results mainly from a shorter growing season and less resistance to spring drought. A very important asset of spring wheat is its higher grain quality than of winter wheat (Kocoń, 2005; Cacak-Pietrzak *et al.*, 2014). However, it should be emphasized that this fact is now less important than in previous decades, when, in terms of quality, spring wheat clearly dominated over winter varieties. Among the registered varieties of winter wheat, only some were characterized by genetically determined high quality of grain.

In the first decade of this century, some breeders have started to advertise the bread spring varieties they have grown, as also suitable for autumn sowing term. In research centers, field experiments were carried out to study the suitability of spring wheat forms for autumn sowing. They pointed out, among other things, that sowing spring forms at the autumn term has many advantages, which in particular cause a prolongation of the growing season, especially at the start of tillering (BBCH – 22) and shooting (BBCH – 32) phase (Rudnicki, Jaskulski, & Dębowski, 1999; Grocholski *et al.*, 2007; Kurowski & Bruderek, 2009; Kardasz, Bubniewicz, & Bączkowska, 2010). According to these authors, an important advantage of autumn sowing term of spring wheat is also the increase of plant resistance to spring drought.

The articles in popular and popular-science press show that the group of producers which sow spring varieties in the autumn term is relatively large. Farmers decide on the sowing date of varieties mainly after plants that leave the field late, e.g., potatoes, beets and maize. That is why these varieties are usually called „alternative wheat". Such a term in relation to these varieties is also used by the authors of scientific papers (Hnilička *et al.*, 2005; Grocholski *et al.*, 2007; Weber & Kaus, 2007; Wenda-Piesik & Wasilewski, 2015). There are a few scientific papers dealing with the subject, but they do not fully cover the problem of sowing the varieties of spring cereals during the autumn. In the world cultivation of cereals we can distinguish spring forms sown in spring, winter forms sown in autumn, and transitional forms, sown both in autumn and spring (Listowski, 1963). A significant difference between winter and spring genotypes lies in the fact that spring plants require a higher temperature during the development period than winter cereals (Gumiński, 1977). According to Listowski (1963), the winter and spring wheat differs in the requirements for the development stage, and particularly at the stage of vernalization. The winter wheat seeds can withstand short-term temperature decrease in the range from -4 °C to -12 °C (Listowski, 1963). Seeds of winter cereals sown in spring germinate normally, but they do not bloom. Thus, they do not release seeds despite the fact that external conditions are beneficial. Winter wheat without passing through the winter period (vernalization) are not capable of a fully normal development (Gumiński, 1977). Very important is freezing tolerance that is the result of physiological, chemical and physical reactions and modifications of plant cell structure, which take place at appropriate developmental stages and under suitable environmental conditions. This process is called hardening or acclimation. Acclimation proceeds in two stages, dependent on the sequential action of chilling (more than 0 °C) and freezing (-3 ° to -5 °C) temperatures (Braun & Saulescu, 2002). In addition to winter and spring forms, there is also an intermediate form – transitional, which can be sown both in autumn and spring (Listowski, 1963). According to Stelmakh (1998), such varieties are characterized by higher light requirements, smaller requirements in terms of vernalization, and lower tolerance to low temperatures. They start earlier spring vegetation and blooming. They occur both as spring and winter genotypes. Variations included in the intermediate form have their country-specific terms. In Russia, these are 'dwurutschki', in Hungary – 'jaro', in Germany – 'die Wechselweizen' (Hnilička *et al.*, 2005). In former Yugoslavia, they are called 'intermediete' 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 yield and the technological value of the grains of selected spring wheat varieties.

Materials 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 Bezek, (51°12′06″N 23°16′06″E), the Lubelskie voivodeship, Poland, belonging to the Central Research Center for Varieties of Cultivated Plants (COBORU).The basis for the research were two-factor field experiments, in 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 (Institute of Soil Science and Plant Cultivation – State Research Institute) 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 second order factor (B) was the spring wheat variety: 'Tybalt', 'Cytra', 'Bombona', 'Monsun', 'Parabola'. All tested cultivars had increased frost resistance compared to the standard spring genotypes. The experiments were located on Calcaric Leptosols, soil quality class III b. The plot area was 15 m^2.

Table 1

Dates of spring wheat sowing in growing seasons

Growing season	Dates of sowing		
	I	II	III
2008/2009	24.10.2008	14.11.2008	3.04.2009
2009/2010	4.11.2009	21.11.2009	31.03.2010
2010/2011	6.11.2010	20.11.2010	25.03.2011

The content of K_2O in the soils on which the experiments were established, was at a high and very high level, and also the P_2O_5 content was at a very high level (Table 2). The soil was characterized by high magnesium content. The analysis showed that soil was alkaline. Soil pH value was 7.5. The soil was suitable for wheat growing.

Table 2

Soil content

Vegatation season	P_2O_5	K_2O	Mg
2008/2009	45.9	37.3	1.7
2009/2010	35.0	28.0	2.7
2010/2011	46.5	28.0	3.2

Mineral fertilization with phosphorus and potassium was applied depending on soil nutrient content, while nitrogen was used depending on the predicted level of grain yields. The amounts of doses used for individual components are shown in Table 3.

Table 3

Mineral fertilization dose in particular vegetation seasons

Vegetation season	N ($kg \cdot ha^{-1}$)	P_2O_5 ($kg \cdot ha^{-1}$)	K_2O ($kg \cdot ha^{-1}$)
2008/2009	150	64	96
2009/2010	150	64	96
2010/2011	148	60	90

The seeding rate of wheat was 500 grains·m^{-2}. After reaching full maturity, the harvest was collected using a combine harvester. The following values were determined: grain yield at 14% of moisture, weight of 1000 grains, number of grains per plant, number of grains per ear, grain yield per plant and grain yield per ear. Plant material samples were collected from the 1m^2 and based on biometric measurements the following parameters - number of grains per plant, number of grains per ear, grain yield per plant and grain yield per ear – were determined.

Statistical evaluation was carried out using the Statgraphics Centurion v. XVI. Analysis of variance was performed with Tukey's confidence interval at a significance level of α=0.05.

Results and Discussion

Meteorological conditions during the research period varied depending on the year of research (Table 4). In all vegetation seasons weather conditions at the time of wheat sowing were good in terms of both temperature and precipitation. The most dangerous were the low temperatures in the winter months, because the wheat could not have survived during this time. In the 2009/2010 growing season, the average January temperature was -9.9 °C, but the plants did well. Weather conditions were also favorable for the wheat maturity.

Sowing date significantly influenced the yield of the spring wheat grain (Table 5). The highest yield was obtained when wheat was sown in the first autumn term (the third decade of October). The average yield from plots where wheat was sown in November (Term II) was similar to wheat sown in Term I. (6.98 and 7.26 t·ha^{-1}, respectively). The average yield of spring-sown wheat (Term III) was significantly lower compared to autumn-sown wheat (Terms I and II). Significant differences were also observed among the studied cultivars in grain yields. On average, 'Tybalt' cultivar was characterized by the highest grain yield and 'Cytra' cv. by the lowest grain yield. A relatively small number of plants of the 'Cytra' cv. per unit area had a large impact on the lowering of the average value of this variety with the first sowing date. Higher yielding of spring wheat from autumn sowing term is undoubtedly the effect of better resistance of plants to the stress of the spring period, mainly related to water shortages. Our own research did not concern the root system, but it should be assumed that it was the better rooting of plants at the time when there was a precipitation shortage (which in Polish climate is the norm and so occurred in each year of research) better to survive this stress. Greater resistance to drought stress also means better use of nutrients by plants. Visual evaluation of wheat crops during the growing season indicated this very clearly.

The genetic factor and variety had a significant impact on the level of obtained grain yields. The authors dealing with the issues of alternative wheat drew attention to this (Weber & Kaus, 2007; Kardasz, Bubniewicz, & Bączkowska, 2010). Some varieties of spring wheat ('Olimpia' and 'Helia') tended to have higher yields during late autumn seasons compared to the effects of spring sowing, while others ('Zebra', 'Torka' and 'Nawra') showed a reverse tendency in this respect, and thus have been identified by the authors as unsuitable for autumn sowing. One of the varieties, despite the increased frost resistance ('Olimpia'), was also included in the group not suitable for autumn sowing, and the reason for this was a high instability of yielding. In these studies, winter wheat varieties were used for comparisons. None of the tested varieties of spring wheat matched the yield of winter wheat varieties (Weber & Kaus, 2007). Sowing of alternative varieties in the late autumnal period increased the yield by approximately 37% compared to the results of spring sowing (Ozturk, Caglar, & Bulut, 2006). Research conducted by other authors (Grocholski *et al.*, 2007) indicate that the advantage of autumn over

Table 4

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	9.8	6.8	4.8	7.8	60.3	92.1	14.3	40.0
November	4.2	4.9	6.0	2.6	26.7	74.4	45.0	32.0
December	0.3	-1.9	-4.7	-1.6	28.0	40.6	34.6	30.0
January	-2.1	-9.2	-1.2	-3.4	15.5	29.4	30.5	24.0
February	-1.8	-3.1	-4.9	-2.4	21.5	30.4	24.9	23.0
March	0.9	2.5	2.2	1.7	52.5	20.8	10.1	25.0
April	10.4	9.0	9.9	7.9	10.1	20.4	30.6	40.0
May	13.9	14.5	14.2	13.7	86.8	72.4	40.8	59.0
June	19.0	17.6	18.2	16.5	180.5	94.4	88.5	76.0
July	19.5	20.8	18.8	18.4	50.8	156.0	178.9	82.0
August	18.0	19.7	18.4	17.8	46.9	141.9	38.5	65.0
Mean (October–August)	8.37	7.42	7.43	7.18	52.69	70.25	48.79	45.1

Table 5

Yield of spring wheat (t·ha^{-1}) in Bezek (mean in the years 2009 – 2011)

Sowing term (A)	Cultivar (B)					
	Tybalt	Cytra	Bombona	Monsun	Parabola	Mean
I	8.00	6.49	7.13	7.59	7.08	7.26
II	7.49	6.29	6.79	7.18	7.14	6.98
III	6.95	5.36	5.77	6.07	6.42	6.11
Mean	7.48	6.05	6.56	6.94	6.88	–
$LSD_{0.05}$ for A = 0.403; B = 0.405; B/A = n.s.						

n.s. – differences not significant (p>0.05)
I – October, II – November, III – Spring

Table 6

Number of plants per 1m^2 in Bezek (mean in the years 2009 – 2011)

Sowing term (A)	Cultivar (B)					
	Tybalt	Cytra	Bombona	Monsun	Parabola	Mean
I	364	280	350	356	350	340
II	319	343	334	354	339	338
III	325	317	336	326	341	329
Mean	336	313	340	346	343	–
$LSD_{0.05}$ for A = n.s.; B = n.s.; B/A = 62.0						

n.s. – differences not significant (p>0.05)
I – October, II – November, III – Spring

spring sowing in wheat yielding was very high. Very large yield increase due to autumn sowing instead of spring wheat was obtained by Kardasz, Bubniewicz, & Bączkowska (2010); it was within 43.2–65.6% depending on the variety. The favorable effect of the autumn sowing date on the yield of wheat grain from the east has also been indicated by Sułek, Nieróbca, & Cacak-Pietrzak (2017). Also in the research conducted by Ozturk, Caglar, & Bulut (2006), the spring wheat sown in the first week of September had a higher grain yield than the delayed autumn and spring-sown wheat. The optimum time of sowing was winter for the facultative cv. 'Kirik'. Grain yields from delayed autumn and spring sowing were low, which was largely the result of hastened crop development and high temperatures during and after anthesis.

The number of plants per 1 m^2 did not depend significantly on the sowing date of wheat (Table 6). There was only a tendency to reduce the number of plants when wheat was spring sown. The role of the variety in developing the number of plants was also not significant, and the smallest number of plants per 1m^2 was found in the 'Cytra' cultivar. Some authors (Kardasz, Bubniewicz, & Bączkowska, 2010) have drawn attention to the cases of reverse dependence – a larger number of plants in autumn

Table 7

Number of ears per 1m^2 in Bezek (mean in the years 2009 – 2011)

Sowing term (A)	Cultivar (B)					
	Tybalt	Cytra	Bombona	Monsun	Parabola	Mean
I	616	496	516	549	535	542
II	461	489	535	612	526	544
III	537	457	592	484	551	524
Mean	538	481	547	548	537	–
$LSD_{0.05}$ for A = n.s.; B = 57.9; B/A = 104.8						

n.s. – differences not significant (p>0.05)
I – October, II – November, III – Spring

Table 8

Productive tillering of spring wheat in Bezek

Years	Sowing term (A)	Cultivar (B)					
		Tybalt	Cytra	Bombona	Monsun	Parabola	Mean
2009	I	1.76	2.17	1.48	1.70	1.73	1.73
	II	1.84	1.60	1.74	1.70	1.66	1.70
	III	1.81	1.53	1.65	1.62	1.70	1.66
Mean		1.80	1.72	1.62	1.67	1.70	–
$LSD_{0.05}$ for A = n.s.; B = 0.170; B/A = 0.500							
2010	I	1.63	1.65	1.47	1.38	1.55	1.53
	II	1.31	1.19	1.43	1.50	1.45	1.38
	III	1.44	1.40	1.52	1.46	1.45	1.45
Mean		1.46	1.40	1.47	1.45	1.49	–
$LSD_{0.05}$ for A = 0.120; B = n.s.; B/A = n.s.							
2011	I	1.68	1.35	1.67	1.65	1.62	1.60
	II	1.67	1.26	1.77	1.75	1.51	1.60
	III	1.47	1.16	1.69	1.57	1.46	1.59
Mean		1.60	1.26	1.71	1.66	1.53	–
$LSD_{0.05}$ for A = n.s.; B = 0.300; B/A = n.s.							

n.s. – differences not significant (p>0.05)
I – October, II – November, III – Spring

sowing, which has been explained by a smaller fallout of better-rooted and more resistant to moisture deficiencies of plants from autumn sowing. According to other authors (Sułek, Nieróbca, & Cacak-Pietrzak, 2017), a smaller number of plants per unit area was obtained when the wheat was sown in autumn.

The impact of experimental factors on the number of ears per unit area was similar over the years. A selection of cultivars significantly affected the number of ears per unit area (Table 7). The largest ear density was found in 'Monsun' and 'Bombona' cultivars, and significantly lowest in 'Cytra' cv. However, the sowing date did not significantly affect the density of spikes per unit area. It should be noted, however, that there was an interaction of experimental factors, which was associated with a larger number of spikes in the Monsun cultivar at the second sowing date and Tybalt cultivar sown in the first sowing term. Similar results were obtained by Kardasz, Bubniewicz, & Bączkowska (2010), because the spring wheat sown in the autumn also developed a larger number of ears per unit area in comparison with the one sown in the spring time. Fotyma (2003) compared the number of spikes per unit area in winter wheat in spring time, and he found a larger number of spikes in the winter form of this species. However, this regularity was subject to modifications over the years, which was caused by the frost of plants in the winter. A productive tillering is a factor that significantly affects the number of spikes (Wenda-Piesik & Wasilewski, 2015). Wheat sown in autumn begins the phase of tillering in the early spring, which lasts longer than in the case of wheat sown in the optimal spring time.

The influence of tested experimental factors on productive tillering of spring wheat depended on the year of research (Table 8). In 2009 and 2011, this feature of plants did not depend on the date of sowing, however, in 2010 the propagated plants sown in the second period (in November) were significantly weaker than those sown 2 weeks earlier (in October). According to other authors (Sułek, Nieróbca, & Cacak-Pietrzak, 2017), plants of wheat sown in spring are characterized by a better productive tillering to those sown in autumn.

The synthesis of research results from the three years of experiments carried out in Bezek showed that the weight of 1000 grains significantly depended on experimental factors (Table 9). With the delay of sowing time, the weight of thousand grains decreased. On average, 'Cytra' cultivar was characterized by a significantly smaller (than the other varieties) weight of 1000 grains (WTG). Among all the tested cultivars, the greatest 1000 grain weight (WTG) was achieved by the 'Parabola' cv. Between these two cultivars, the difference was 25%. Studies conducted by other authors also indicate that wheat sown in autumn is characterized by a higher weight of 1000 grains compared to spring sown wheat (Grocholski *et al.*, 2007; Kardasz, Bubniewicz, & Bączkowska, 2010; Sułek, Nieróbca, & Cacak-Pietrzak, 2017).

Table 9

Thousand grain weight (g) (mean in the years 2009 – 2011)

Sowing term (A)	Cultivar (B)					
	Tybalt	Cytra	Bombona	Monsun	Parabola	Mean
I	43.17	38.57	40.90	43.86	50.96	43.49
II	42.38	36.48	41.99	42.46	49.79	42.62
III	42.64	35.92	37.27	40.53	47.00	40.67
Mean	42.73	36.99	40.05	47.00	49.25	–
$LSD_{0.05}$ for A = 2.030; B = 2.450; B/A = 3.450						

I – October, II – November, III – Spring

Conclusions

1. A positive effect of the autumn sowing term on the yield of spring wheat grain was found. Grain yield of wheat sown in the first autumn sowing date was statistically significantly higher than wheat sown in spring (the difference was 1.15 t·ha^{-1})
2. The number of plants per area unit did not depend significantly on the factors of the experiment, which means that the plants sown in autumn perfectly survived the winter period. Thus, it can be stated that there were no harmful effects of frost on plants.
3. No significant effect of the sowing date on the number of spikes per unit area was found. Only the selection of the cultivar affected this. The largest number of ears was found in the following cultivars: 'Monsun', 'Bombona', 'Parabola' and 'Tybalt', while the lowest in the 'Cytra' cv.
4. The production distribution depended on the years of research. In 2009 and 2011, the sowing date did not affect this. However, in 2010, by sowing wheat in the first date, the largest production spreading was achieved.
5. The weight of a thousand grains depended heavily on the experimental factors. The later sowing date resulted in a lower weight of 1000 grains. Cultivar 'Parabola' was characterized by the highest WTG.

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