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Reaction of facultative cultivars of spring wheat to autumn and spring sowing dates

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Abstract. The aim of the study was to evaluate the reaction of facultative cultivars of spring wheat to autumn and spring sowing dates. Sowing of facultative cultivars in autumn is justified especially after late forecrop (sugar beet, maize for grain), when the optimal date of sowing of winter wheat has passed. A replicated field experiment was carried out in the seasons 2013/2014–2015/2016. Three cultivars of spring wheat: Bombona, Ostka Smolicka and Struna were selected for testing. The autumn vs. spring sowing date of spring wheat was shown to result in a significant increase in rain yield (by 0.7 t ha^{-1}, i.e. 10.8%). The yield increase was the result of an increased number of ears per m^2 and 1000 grain weight in cultivars from autumn sowing. Grain from spring sowing was characterized by a higher content of total protein, phosphorus, calcium, iron, copper and zinc. The autumn sowing date resulted in an increase in the content of potassium in the grain. Struna was marked by a significantly larger number of ears per m^2 compared to that in Ostka Smolicka. Bombona formed a greater number of grains in the ear than Struna, but it developed smaller grains compared to those in Ostka Smolicka. Bombona had the highest total protein and ash content. The grain of Struna contained significantly more starch than Bombona and less crude fibre than Ostka Smolicka. Bombona had a higher content of phosphorus compared to that in Struna, and a higher calcium content than Struna and Ostka Smolicka. High contents of iron, copper and manganese was determined in the grain of Bombona , whereas the grain of Ostka Smolicka was high in zinc.

Keywords: *Triticum aestivum* L., facultative cultivars, sowing date, yield components, yield, chemical composition

INTRODUCTION

Common wheat (*Triticum aestivum*) comprises two forms: winter (*biennis*) and spring (*annua*). Certain cultivars of spring wheat are treated as so-called facultative, because they have a favourable level of winter-hardiness. The autumn sowing of facultative cultivars prolongs the growing period of the plants, improves the tillering and makes better use of the accumulated water from winter rainfall (Grabiński, Wyzińska, 2014; Sułek et al., 2017). The most suitable date for sowing of facultative cultivars is November, which ensures that the plants start developing the first leaf from the leaf sheath (9-BBCH) up to the second and third leaf phase before the winter dormancy period (Grabiński, Wyzińska, 2014). The research conducted so far shows that the facultative cultivars ripen faster, which provides enough time for preparation of the stand for early-seeded winter crops (Ozturk et al., 2006; Neugschwandtner et al., 2015; Wenda-Piesik, Wasilewski, 2015). The average yield increase resulting from autumn sowing of the facultative cultivars may vary from 4,8% (Kurowski, Bruderek, 2009) to 43,2–62,6% (Kardasz et al., 2010) in relation to spring sowing date. However, the autumn sowing of the facultative cultivars is risky due to the increased hazard of the loss to freeze damage in areas with severe winters . Therefore, in worse habitat conditions it is advisable to increase the sowing rate by 10% or more. Additionally, the grain of facultative cultivars from autumn sowings is often of lower quality than the seed obtained from spring crops. However, these are usually slight differences (Grabiński, Wyzińska, 2014; Kardasz et al., 2010; Caglar et al., 2011; Wenda-Piesik, Wasilewski, 2015; Sułek et al., 2017; Wenda-Piesik et al., 2017).

Evaluation of the reaction of spring wheat facultative cultivars to autumn and spring sowing dates was the main aim of the study.

MATERIALS AND METHODS

A replicated field experiment with facultative cultivars of spring wheat was conducted in the Podkarpackie Agricultural Advisory Centre in Boguchwała (21°57’E 49°59’N) in the seasons 2013/2014–2015/2016. It was

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a two-factorial experiment, carried out as a split-block design with three replications. The first factor examined was the date of sowing: autumn and spring, while the second factor was the cultivar: 'Bombona', 'Ostka Smolicka' and 'Struna'. Bombona is characterized by a very good chemical composition of grain. Ostka Smolicka and Struna provide a high yield of good quality.

The weather conditions are given according to the records of the Podkarpackie Agricultural Advisory Centre. The experiments were established on a medium-heavy soil brown soil, a very good wheat complex, of the II soil quality class. The soil reaction was slightly acidic and the humus content was medium high. The content of available phosphorus and potassium was high whereas that of magnesium was medium-high (Table 1). Soil samples were analyzed at the Regional Chemical-Agricultural Station in Rzeszów.

Table. 1. Chemical analysis of the soil.

Parameter	Unit	2013	2014	2015
pH in KCl	-	6.5	6.4	5.9
Humus	%	1.52	1.32	1.28
P_2O_5	mg $(100\ g)^{-1}$ soil	19.5	18.7	18.2
K_2O		23.5	24.1	22.0
Mg		6.7	6.5	5.5

The area of a single plot was 15.0 m^2. The grain was sown to the depth of 3 cm and row-to-row spacings were 12.5 cm. The forecrop was maize grown for grain. The seed was treated with Funaben Plus 02 WS. Spring sowing was performed on the following dates: 26.03.2014, 24.03.2015 and 22.03.2016. Autumn sowing was carried out on 14.11.2013, 12.11.2014 and 9.11.2015. The standard seeding rate was 500 grains m^{-2}. During the growing period, the plants were chemically protected. In the case of wheat sown in autumn, Huzar Activ 387 OD and Sekator 125 OD were applied for weed control, Karate Zeon 050 CS was used against pests, and Topsin M 500 S.C. and Wirtuoz 520 E against diseases. The herbicide Sekator 125 OD, insecticide Cyperkill Max 500 EC and fungicide Falcon 460 EC and Artea 330 EC were applied to cultivars sown in spring. In the BBCH 32 phase, regardless of the date of sowing, two growth regulators were used jointly (Antywylegacz 675 SL + Modus 250 EC).

Phosphorus and potassium fertilization was carried out in autumn at rates of 60 and 90 kg ha^{-1}, respectively. Nitrogen fertilization was applied at two rates: 80 and 40 kg ha^{-1}. Nitrogen fertilization was applied to wheat sown in autumn before the start of vegetation at the BBCH 25 phase and split-applied to spring-sown wheat: pre-plant and at the BBCH 25 phase.

The ear density was calculated on an area of 1 m^2 before harvesting. The number of grains per spike and the weight of 1000 grains was determined on plants collected from 0.5 m^2. Wheat grain harvest from spring sowings was carried out on days: 3.08.2014, 12.08.2015 and 8.08.2016. Wheat grain harvest from autumn sowings was performed on: 29.07.2014, 31.07.2015 and 22.07.2016. The grain yield was converted to 1 ha at 14% moisture content.

The content of total protein, starch, crude ash and crude fibre in grain was determined by means of the near infrared method on the FT-LSD MPA spectrometer (Bruker company, Germany).

Macro- and microelements were measured in the Laboratory of the Faculty of Biology and Agriculture of the University of Rzeszów. In order to determine particular elements, grain samples were mineralized in HNO_3: $HClO_4$: H_2SO_4 at 20:5:1, in an open system in Tecator heating block. Ca, K, Mg, Zn, Mn, Cu, Fe contents were determined in the samples by flame atomic absorption spectroscopy (FAAS) using Hitachi Z-2000 apparatus (Japan). Shimadzu UV-VIS spectrophotometer (Japan) was used to analyze phosphorus (P) by vanadium-molybdenum method.

Since no significant interactions of experiment factors x years were found by ANOVA the data were averaged across the years of the experiment and the means were examined for significant differences using Tukey's HSD. Calculations were performed with the statistical program ANALWAR-5.3.FR. .

RESULTS AND DISCUSSION

The weather conditions varied over the years. Generally, the sowing of facultative cultivars was carried out under favourable conditions. The air temperature in November each year exceeded the long-term average, with low rainfall in 2014. Winter in 2013/2014 and 2014/2015 was mild. In the 2015/2016 season, January temperature oscillated at the level of the long-term average. Summer precipitation was highly variable and unevenly distributed. Air temperatures differed from the long-term averages to a smaller extent, though (Fig. 1).

The climate changes observed in Poland in recent years, including an increase in temperatures in spring and milder winters (Górski, Kozyra, 2011), support the validity of research on the sowing of facultative wheat cultivars in the autumn. Sułek et al. (2017) report that lower yields of spring wheat grain in the seasons 2008/2009 and 2009/2010, especially from the spring sown crops, were caused by worse weather conditions, very low precipitation during the sowing and emergence period in particular. Biskupski et al. (2007) found the yields of spring wheat sown in spring, to be significantly affected solely by weather conditions prevailing during the years of their study. Therefore, the autumn sowing of the facultative cul-

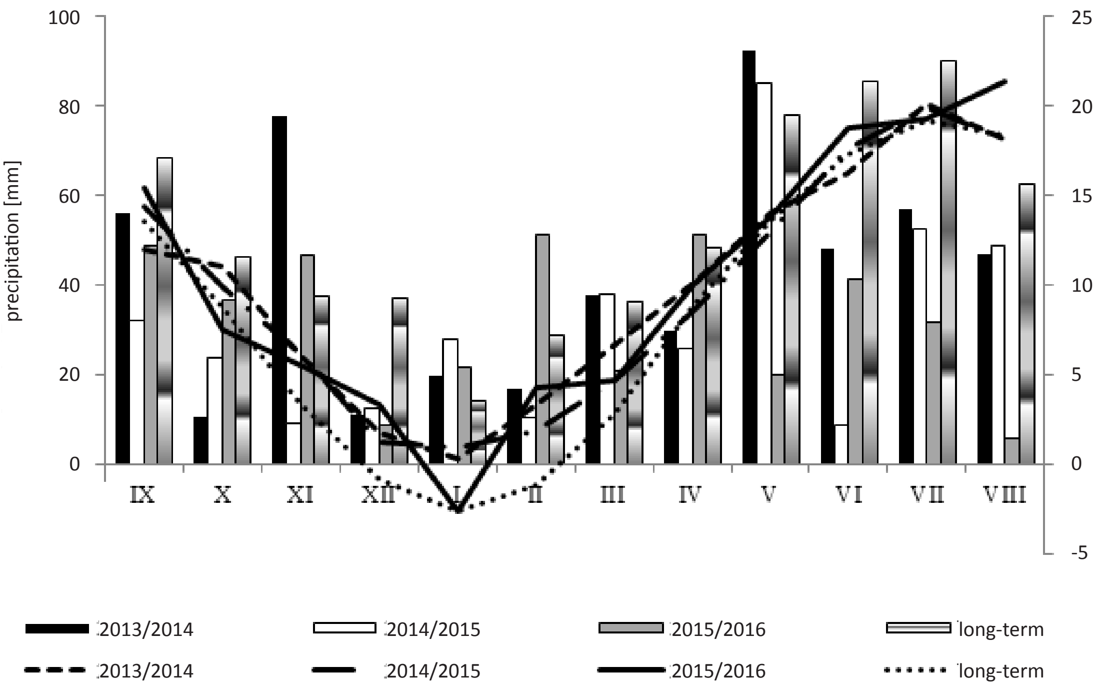

Figure 1. The course of weather conditions.

tivars can smooth away the reductions in yield of spring wheat that result from the occurrence of spring droughts. Oleksiak (2014) believes that because of changing climatic conditions in Poland, genetic improvement or changing assortment of cultivars, it is also necessary to analyse and correct recommendations concerning sowing dates for winter wheat.

In this study, the sowing of wheat grain in the autumn resulted in a significant increase in the number of ears per m^2 and in thousand grain weight. As a result, the yield of grain from autumn sowing was higher by 0.7 t ha^{-1}, i.e. by 10.8% compared to the yield obtained from spring sowing. Cultivar Struna was characterized by a significant higher number of ears per m^2 compared to Ostka Smolicka. In turn, Bombona produced a higher number of grains per spike than did Struna. The highest weight of 1000 grains was recorded in Ostka Smolicka, significantly smaller than that in Bombona. Of the cultivars studied, Ostka Smolicka gave the highest yield, 7.2 t·ha^{-1} on average. This cultivar reacted most beneficially to the autumn sowing date (Table 2).

Studies conducted by a number of authors (Ozturk et al., 2006; Grocholski et al., 2007; Kurowski, Bruderek, 2009; Kardasz et al., 2010; Neugschwandtner et al., 2015; Wenda-Piesik, Wasilewski, 2015; Wenda-Piesik et al., 2016; Sułek et al., 2017) indicate a beneficial effect of the autumn sowing date on yields of spring wheat. At the same time, yield increases reported by the above-mentioned investigators varied among the individual reports. Weber and Kaus (2007) confirm that the yields of the facultative cultivars sown in the autumn are variable and depend on many factors, including the variety. Wenda-Piesik and Wasilewski (2015) recorded higher yields of facultative cultivars sown at the turn of November and December than from those sown in October. This was influenced by better overwintering of crops sown at a later date, from which a better ear density per area unit was obtained. Grocholski et al. (2007) proved that all spring wheat facultative cultivars reacted favourably to late autumn vs. spring sowing date. The grain yield thus obtained was higher by 33.6%, with significant variety-to-variety differences for thousand grain-weight s. Sułek et al. (2017) state that the advantage of autumn vs. spring sowing of the spring wheat cultivar Cytra were a higher grain yield grain yield and a higher number of grains per ear plus increased productive tillering. In Wenda-Piesik and Wasilewski's research (2015), on the other hand, the higher number of grains per ear and the increased weight of 1000 grains were the yield components that made another spring wheat variety cv. 'Monsun' give higher yields when sown in late autumn than when sown in spring.

Sowing of the facultative cultivars in spring resulted in a significant increase of the total protein content in grain compared to autumn sowing. The difference was 0.8 percentage points. The cultivars differed significantly for the chemical composition of grain. The highest content of total protein and crude ash was found in the grains of Bombona. The grain of Struna contained significantly more starch

Table 2. Yield and yield components.

Sowing date (A)	Cultivar (B)	Number of ears [pcs. m^{-2}]	Number of grains per ear	Thousand grain weight [g]	Grain yield [t ha^{-1}]
Autumn	Bombona	509.5	35.4	38.6	6,9
	Ostka Smolicka	515.0	34.8	44.0	7,8
	Struna	518.3	34.0	39.5	6,9
Spring	Bombona	498.3	35.6	36.6	6,4
	Ostka Smolicka	479.2	34.6	39.7	6,5
	Struna	506.9	33.4	39.2	6,6
Interaction A×B		n.s.	n.s.	n.s.	n.s.
Autumn		514.3	34.7	40.7	7.2
Spring		494.8	34.5	38.5	6.5
HSD $_{0.05}$ A		18.6	n.s.	1.98	0.58
Bombona		503.9	35.5	37.6	6.7
Ostka Smolicka		497.1	34.7	41.9	7.2
Struna		512.6	33.7	39.4	6.8
HSD $_{0.05}$ B		14.2	1.65	3.57	0.34
2014		495.2	38.6	37.0	7.1
2015		560.5	31.3	44.4	7.8
2016		457.8	33.9	37.4	5.8
Mean total		504.5	34.6	39.6	6.9

n.s. – non-significant differences

Table 3. Content of the components in the seeds in % D.M.

Sowing date (A)	Cultivar (B)	Total protein	Starch	Crude fibre	Crude ash
Autumn	Bombona	14.1	62.5	1.95	2,01
	Ostka Smolicka	13.0	61.4	2.25	1,85
	Struna	13.1	63.1	1.76	1,72
Spring	Bombona	14.9	61.1	2.07	1,99
	Ostka Smolicka	13.8	62.7	2.07	1,87
	Struna	13.9	64.3	1.86	1,72
Interaction AxB		n.s.	n.s.	n.s.	n.s.
Autumn		13.4	62.3	1.99	1.86
Spring		14.2	62.7	2.00	1.86
HSD $_{0.05}$ A		0.72	n.s.	n.s.	n.s.
Bombona		14.5	61.8	2.01	2.00
Ostka Smolicka		13.4	62.1	2.16	1.86
Struna		13.5	63.7	1.81	1.72
HSD $_{0.05}$ B		0.86	1.75	0.31	0.24
2014		14.3	60.1	2.09	1.97
2015		13.9	62.2	1.85	1.75
2016		13.2	65.2	2.03	1.86
Mean total		13.8 -	62.5	1.99	1.86

n.s. – non-significant differences

than that of Bombona but significantly less crude fibre than Ostka Smolicka (Table 3).

Neugschwandtner et al. (2015) indicate that the wheat sown in spring had a high nitrogen content in grain and straw. However, the efficiency of accumulated nitrogen was higher for autumn sowing due to higher grain and straw yields. In research of Wenda-Piesik et al. (2017) grain of spring wheat sown in March was characterized by a higher protein content, higher amount of gluten and higher rate of sedimentation index than from late autumn sowing. Autumn sowing, on the other hand, had a positive effect on the bulk density of grain and the value of falling number. Numerous authors (Kardasz et al., 2010; Caglar et al., 2011; Grabiński, Wyzińska, 2014; Wenda-Piesik, Wasilewski, 2015; Sułek et al., 2017; Wenda-Piesik et al., 2017) note that spring wheat grain of better end-use and processing value is obtained from spring sowing than from autumn sowing. However, these reductions are not very large.

The spring sowing of the facultative cultivars in comparison with the autumn sowing resulted in an increase in the content of phosphorus and calcium in the grain and a decrease in the content of potassium. Bombona was characterized by a higher content of phosphorus in comparison with Struna, while calcium in comparison with Struna and Ostka Smolicka. Jarecki et al. (2019) also obtained a significant variety-to variety differentiation in the content of macroelements in the grain of spring wheat facultative cultivars. The investigators also demonstrated a large influence of weather conditions on the macroelement content in grain.

Spring sowing of wheat caused an increase in the contents of iron, copper and zinc in grain

Table 4. Content of macroelements in the seeds (g kg^{-1} D.M.).

Sowing date (A)	Cultivar (B)	Phosphorus	Potassium	Calcium	Magnesium
Autumn	Bombona	3.25	28.3	0.32	0.83
	Ostka Smolicka	2.43	29.7	0.29	0.77
	Struna	2.60	29.6	0.39	0.99
Spring	Bombona	3.37	24.8	0.79	0.95
	Ostka Smolicka	3.21	31.9	0.58	0.94
	Struna	2.57	18.8	0.48	0.89
Interaction A×B		n.s.	n.s.	n.s.	n.s.
Autumn		2.76	29.2	0.33	0.86
Spring		3.05	25.1	0.62	0.93
HSD $_{0.05}$ A		0.25	3.45	0.17	n.s.
Bombona		3.31	26.5	0.55	0.89
Ostka Smolicka		2.82	30.8	0.43	0.85
Struna		2.58	24.2	0.43	0.94
HSD $_{0.05}$ B		0.68	5.48	0.11	n.s.
2014		3.02	28.1	0.55	0.96
2015		2.81	26.5	0.44	0.83
2016		2.90	26.9	0.45	0.92
Mean total		2.91	27.18	0.48	0.90

n.s. – non-significant differences

Table 5. Content of microelements in the seeds (mg kg^{-1} D.M.)

Sowing date (A)	Cultivar (B)	Iron	Copper	Zinc	Manganese
Autumn	Bombona	57.12	1.68	13.42	22,18
	Ostka Smolicka	35.00	1.18	13.50	19,50
	Struna	43.36	1.28	13.40	20,60
Spring	Bombona	57.28	1.78	24.82	23,78
	Ostka Smolicka	48.44	2.06	31.92	21,93
	Struna	43.28	1.55	18.78	19,75
Interaction A×B		n.s.	n.s.	n.s.	n.s.
Autumn		45.16	1.38	13.44	20.76
Spring		49.67	1.80	25.17	21.82
HSD $_{0.05}$ A		3.56	0.37	9.63	n.s.
Bombona		57.22	1.73	19.12	22.98
Ostka Smolicka		41.72	1.62	22.71	20.71
Struna		43.32	1.41	16.09	20.17
HSD $_{0.05}$ B		11.31	0.29	5.37	2.49
2014		49.36	1.72	20.21	21.98
2015		45.33	1.35	18.22	20.23
2016		47.54	1.69	19.51	21.66
Mean total		47.41	1.59	19.31	21.29

n.s. – non-significant differences

compared to those from the autumn sowing date. The highest content of iron, copper and manganese was determined in the grain of Bombona, while in the grain of Ostka Smolicka – zinc. In the research of Jarecki et al. (2019) similar contents of microelements were found. Additionally, they showed a variability in chemical composition over the years of the study. Gondek and Gondek (2010) report that the content of copper in wheat grain and straw was deficient in terms of feed value, while the content of zinc was within the optimal range.

CONCLUSIONS

1. Sowing of spring common wheat in autumn resulted in a significant increase in grain yield by 0.7 t ha^{-1}, i.e. 10.8% compared to the yield obtained from spring sowing. Higher yields of facultative cultivars sown in the autumn resulted from an increased number of ears per m^2 and the weight of thousand grains.
2. The higher content of crude protein, phosphorus, calcium, iron, copper and zinc was characteristic for grain obtained from spring sowings. The autumn sowing date resulted in an increase in potassium content in the grain.
3. The cultivars studied differed significantly for yield components and for chemical composition of grain. Ostka Smolicka gave the highest overall grain yields, 7.2 t ha^{-1} on average and also gave the highest grain yield in autumn sowing treatments.

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