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ORIGINAL PAPER

RESPONSE OF FACULTATIVE CULTIVARS OF SPRING WHEAT TO AUTUMN SOWING AND FOLIAR FERTILIZATION*

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Abstract

Facultative cultivars of spring cereal crops can be sown in autumn. Late autumn planting of spring wheat may foster the faster growth and development of seedlings in early spring when soil water from winter storage is more likely to be available. Mineral fertilization is an important element of spring wheat cultivation technology, affecting the volume and quality of grain yield. During the growing season, nutrients can be provided to the plants by foliar application. In the seasons 2013/2014 - 2015/2016, a controlled field experiment was carried out to investigate the response of facultative cultivars of spring wheat (Bombona, Ostka Smolicka, Struna) to the autumn sowing date and foliar fertilization (Insol 3). The experiments were established in medium soil of the very good wheat complex, soil quality class II. It was shown that the cultivar Struna was characterized by a high spike density per 1m^2 and the high content of starch, phosphorus, magnesium, iron and manganese in grain. The cultivar Ostka Smolicka was distinguished by the highest values of such traits as TGW, grain yield, the SPAD index and the content of potassium and zinc in grain. The grain of the cultivar Bombona contained the largest amount of protein. The assessed quantitative and qualitative traits of the tested cultivars were varied in the years of the study. The difference in grain yield between 2014 and 2015 was 1.69 t ha^{-1}. Foliar fertilization significantly increased the SPAD index, TGW, grain yield, as well as the magnesium and iron content in the grain compared to the control treatment. The resulting increase in grain yield after the application of Insol 3 foliar fertilizer was 0.31 t ha^{-1} as compared with the control.

Keywords: *Triticum aestivum* L., facultative varieties, foliar fertilizers, SPAD values, yield components, yield, chemical composition.

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INTRODUCTION

Common wheat (*Triticum aestivum* L.) belongs to the family *Poaceae*. Two forms of wheat are cultivated: winter and spring. Some varieties of spring wheat can be grown as facultative crops (Veisz et al. 2001, Grabiński, Wyzińska 2014, Sułek et al. 2017). Sowing of facultative cultivars in autumn is justified especially after late previous crops like sugar beet or maize for grain. The best date for sowing facultative crops is November, which guarantees the entry of plants before the winter into the pinning phase, the maximum of the second or third leaf (Grabiński, Wyzińska 2014). Facultative cultivars sown in autumn make better use of water accumulated in the soil after winter. Moreover, they mature more quickly, which facilitates proper preparation of the field under early sown winter crops (Ozturk et al. 2006, Neugschwandtner et al. 2015, Wenda-Piesik, Wasilewski 2015). The average yield increase resulting from autumn sowing of facultative crops may be from 4.8% (Kurowski, Bruderek 2009) to 43.2 - 62.6% (Kardasz et al. 2010) in relation to spring sowing. However, the grain of autumnal-sown facultative crops often has a reduced quality compared with the grain obtained from spring sowing (Grabiński, Wyzińska 2004, Kardasz et al. 2010, Caglar et al. 2011, Wenda-Piesik, Wasilewski 2015, Sułek et al. 2017, Wenda-Piesik et al. 2017).

Mineral fertilization is an important element of spring wheat cultivation technology, affecting the volume and quality of grain yield. The effect of mineral fertilization depends on many factors, including: the form of a fertilizer, the date of application, the dose or the method of application (Biskupski et al. 2007, Ali et al. 2012). During the growing season, nutrients can be provided to the plants by foliar application. Szewczuk and Michajłoć (2003) report that as a result of foliar fertilization, crop yields can be expected to grow by 8-20%. Orlik et al. (2005) conclude, however, that it is difficult to accurately determine the effect of foliar feeding on crop yielding, especially when using field research methods. Zebarth et al. (2007) and Hamblin et al. (2014) indicate in the discussed aspect the validity of an assessment of the nutritional status of plants, eg using SPAD (Soil Plant Analysis Development) measurements. Results of the SPAD index allow to determine the needs for fertilizing plants during growth.

The aim of the study was to compare the responses of spring wheat facultative cultivars to autumn sowing and foliar fertilization.

MATERIAL AND METHODS

A controlled field experiments with spring wheat facultative cultivars was located in the Podkarpackie Agricultural Advisory Center in Boguchwała (21°57′E, 49°59′N) in the seasons 2013/2014 - 2015/2016.

It was a two-factor experiment established in a random block design with split-plots in three replications. The first factor studied was the cultivar: Bombona, Ostka Smolicka and Struna. The other factors were a foliar fertilizer (Insol 3) and the control treatment (without foliar fertilization).

The trials were established on medium soil of the very good wheat complex, soil quality class II. It was typical brown soil with slightly acidic pH and an average humus content. It had a low content of N_{min}, high content of available phosphorus and potassium and medium content of magnesium. The soil abundance of microelements was average for copper, zinc, manganese and iron and low for boron. The soil analysis was carried out at the District Chemical-Agricultural Station in Rzeszów, according to the Polish standards. The weather conditions were described according to the data from the Podkarpackie Agricultural Advisory Center.

The area of a single plot was 15.0 m^2. The sowing depth was 3 cm and the row spacing was 12.5 cm. The previous crop was maize for grain. Sowing of dressed seeds (Funaben Plus 02 WS) was done on 15.11.2013, 11.11.2014 and 9.11.2015. The sowing dose was 500 seeds m^{-2}. During the growth, chemical plant protection was carried out against weeds (Huzar Activ 387 OD, Sekator 125 OD), pests (Karate Zeon 050 CS) and diseases (Topsin M 500 SC, Wirtuoz 520 EC). Two growth regulators were used together in the BBCH 32 phase (Antywylegacz 675 SL + Modus 250 EC). Plant protection products were used according to the manufacturer's label.

Fertilization with phosphorus and potassium supplied 60 and 90 kg ha^{-1} of the elements, respectively. Nitrogen fertilization was applied in two pre-sowing and top dressing (BBCH 25) doses, in amounts of 80 and 40 kg ha^{-1}, respectively. Foliar fertilization was applied at a dose of 1.5 dm^3 ha^{-1} in two development phases of wheat, BBCH 33 and BBCH 49. Foliar fertilization was not applied on the control. The fertilizer Insol 3 (INSOL Sp. z.o.o.) contained (as percentage of its mass) nitrogen 15, magnesium (MgO) 4.6, boron 0.28, copper 0.56, iron 1.2, manganese 1.68, molybdenum 0.01 and zinc 1.12.

The ear density was counted over an area of 1 m^2 prior to harvest. The number of grains per ear and and TGW were assessed on 20 randomly collected plants.

During the plant growth, SPAD-Soil Plant Analysis Development measurements (from 0 to 99.9) were made. These measurements were taken twice with an SPAD - 502P chlorophyll meter (Konica Minolta, Japan) in the BBCH 39 and BBCH 59 phases. The tests were carried out on 30 flag leaves on each plot in the morning.

The grain harvest was carried out on 29.07. 2014, 31.07. 2015 and 22.07. 2016. The area to be harvested was 15.0 m^2. The grain yield was converted to 1 ha at 14% grain moisture content.

The grain uniformity assessment was performed with a Sortimat Type K laboratory separator (Pfeuffer, Germany). Each grain sample weighed 100 g.

Grain was sifted through five drawer sieves of various sizes for 3 minutes. The total results of grain uniformity from the two upper sieves (> 2.5 mm) were given as a percentage.

The content of total protein, starch, ash and fiber in the grain was determined with the LSDS method in near-infrared on an FT-LSD MPA spectrometer (Bruker, Germany).

Macroelements and microelements were determined at the Laboratory of the Faculty of Biology and Agriculture of the University of Rzeszów. In order to determine individual elements, grain samples were mineralized in HNO_3: $HClO_4$: HS_2O_4 in a ratio of 20: 5: 1, in an open system of a Tecator heating block. The content of Ca, K, Mg, Zn, Mn, Cu, Fe was determined in the samples by means of flame atomic absorption spectroscopy (FAAS), using a Hitachi Z-2000 apparatus (Japan), while a UV-VIS Shimadzu (Japan) spectrophotometer was used to determine phosphorus (P) with the vanadium-molybdenum method.

Significance of differences between the values of characteristics was found based on the Tukey's confidence half-intervals, at the significance level α = 0.05. The calculations were supported by statistical software FR-ANALWAR-5FR.

RESULTS AND DISCUSSION

The weather conditions were varied in the years of the study. Seeds of facultative cultivars were sown in favourable weather conditions. The air temperature in November each year exceeded the long-term mean. The seasons 2014/2015 and 2015/2016 were warmer in the years of the study, which was confirmed by the mean air temperature in the months of winter dormancy of plants and during their spring and summer growth and grain formation periods. The precipitation totals in the study years in the individual growth periods of facultative crops were evenly distributed. The growing season 2014/2015 was characterized by the lowest amount of precipitation (352.2 mm), deviating from the long-term total by 21.6% (Table 1).

The climate changes observed in recent years in Poland, including the increase in temperature in the spring season as well as milder winters (Górski, Kozyra 2011), indicate the validity of research into the sowing of facultative wheat cultivars in 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 sowing date, were caused by worse weather conditions, mostly a very small amount of rainfall during the sowing and emergence periods. Biskupski et al. (2007) report that the grain yield of spring wheat sown in spring was significantly

Table 1

Weather conditions for three growing seasons

Years	Vegetation period					
	sowing Nov)	winter rest (Dec-Feb)	spring-summer (March-May)	of grain formation (June-July)	M/S	D
Air temperature (°C)						
2013–2014	5.8	–2.3	7.8	18.6	6.9	+0.1
2014–2015	6.2	0.4	11.1	18.9	8.6	+1.8
2015–2016	4.8	1.7	9.1	19.2	8.4	+1.6
*1975–2012	3.6	–1.4	8.6	17.7	6.8	–
Precipitation (mm)						
2013–2014	25.8	113.6	212.7	148.1	500.2	+51.3
2014–2015	20.1	79.2	120.4	132.5	352.2	–96.7
2015–2016	70.1	83.8	178.0	175.6	508.4	+59.5
*1975–2012	33.9	94.9	150.7	169.4	448.9	–

M/S – mean/sum (from sowing to harvest). D – deviations from * multi-annual

affected only by the weather conditions in individual years of the study. Hence the autumn sowing of facultative cultivars can compensate for decreases in the yields of spring wheat resulting from the occurrences of spring drought.

In the present experiment, the cultivar Struna was characterized by a higher ear density (by 8 pieces) as compared with Bombona. Ostka Smolicka was characterized by the highest grain plumpness (TGW 44.6 g). The cultivar Ostka Smolicka gave a higher grain yield by 1.28 t ha^{-1} as compared with Bombona. The yield components and grain yield were variable in years. The highest grain yield was obtained in 2014 and the lowest in 2015 (Table 2).

Many 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 the beneficial effect of autumn sowing dates on the yield of spring wheat grain. At the same time, the yield gains obtained by these authors were very diverse. Weber and Kaus (2007) confirm that the volume of yields of facultative cultivars sown in autumn is variable and depends on many factors, including varietal ones. Wenda-Piesik and Wasilewski (2015) obtained higher facultative crop yields from sowing at the turn of November and December than from crops sown in October. This was affected by better wintering of plantations that were established later, in which a better ear density was obtained. Grocholski et al. (2007) proved that all spring wheat facultative

Table 2

Grain yield and yield components

Variety	Foliar fertilizers	Number of ears (pcs. m^{-2})	Number of grains per ear (pcs.)	Thousand grain weight (g)	Grain yield (t ha^{-1})
Bombona	–	519	31.9	38.6	6.16
	Insol 3	523	32.1	38.9	6.50
Ostka Smolicka	–	525	32.7	44.3	7.51
	Insol 3	523	33.4	44.9	7.71
Struna	–	528	32.0	39.4	6.52
	Insol 3	530	32.5	40.9	6.91
Interaction IxII		n.i.	n.i.	n.i.	n.i.
Bombona		521	32.0	38.8	6.33
Ostka Smolicka		524	33.1	44.6	7.61
Struna		529	32.3	40.2	6.72
LSD $_{0.05}$ I		6.3	n.i.	4.31	1.13
Control		524	32.2	40.8	6.73
Foliar fertilizers		525	32.7	41.6	7.04
LSD $_{0.05}$ II		n.i.	n.i.	0.72	0.28
2014		544	31.4	45.3	7.55
2015		492	33.1	36.3	5.86
2016		539	32.7	42.0	7.26
Mean total		525	32.4	41.2	6.89

n.i. – non-significant differences

cultivars responded favourably to a late-autumn sowing date compared with a spring date. The grain yield obtained was higher by 33.6%, with a significant varietal variation in the thousand grain weight. SUŁEK et al. (2017) report that the yield components which ensured a higher grain yield of the spring wheat cultivar Cytra sown at an autumn date than that sown in spring were: a higher grain weight and the number of grains per ear, as well as an increased productive tilllering of the plants. On the other hand, in the study by WENDA-PIESIK and WASILESKI (2015), the yield components which ensured a higher grain yield of the wheat cultivar Monsun sown at a late autumn date than at a spring date were the number of grains per ear and the 1000 grain weight.

The applied foliar fertilizer did not have a significant impact on the ear density before harvesting or on the number of grains per ear. On average, in the present experiment, the ear density per 1 m^2 was 525 pieces and the number of grains per ear was 32.4 pcs. It was proven, however, that foliar fertilization effected an increase in the TGW and grain yield in comparison to the control treatment. The yield increase obtained after the application of Insol 3 foliar fertilizer was 0.31 t ha^{-1}. SZEWCZUK and SUGIER (2009) conclude that when selecting a foliar fertilizer for a given crop, the concentration of ingredients and the related possibility of meeting the nutritional needs of a given plant should be taken into account. Moreover, there are special additives in some foliar fertilizers that improve their functional properties and increase the assimilation of ingredients.

Plants of the cultivar Ostka Smolicka variety were distinguished by greater SPAD value measurements compared with plants of the cultivar Struna (Table 3). The highest SPAD index measurements were recorded in 2014, while the lowest ones were in 2015. The foliar fertilizer effected a significant increase in the SPAD index in the studied plants in comparison with the control. Higher SPAD was recorded in the BBCH 39 phase compared with the BBCH 59 phase. TREMBLAY et al. (2010) also noted the diversity of SPAD readings in the years of research. VIDAL et al. (1999) and AKHTER et al. (2016) showed the usefulness of SPAD measurements to assess the nutritional status of plants, but mainly depending on the level of nitrogen fertilization. NEUGSCHWANDTNER et al. (2015) report that wheat sown in spring had a high nitrogen content in grain and straw. However, the nitrogen yield was

Table 3

SPAD values and grain fraction

Variety	Foliar fertilizers	SPAD		Grain fraction > 2.5 mm (%)
		BBCH 39	BBCH 59	
Bombona	–	48.3	47.3	83.6
	Insol 3	49.2	47.6	83.9
Ostka Smolicka	–	49.2	48.3	85.3
	Insol 3	51.2	48.9	86.3
Struna	–	45.3	45.0	72.6
	Insol 3	45.9	45.5	73.5
Interaction IxII		n.i.	n.i.	n.i.
Bombona		48.8	47.5	83.8
Ostka Smolicka		50.2	48.6	85.8
Struna		45.6	45.3	73.1
LSD $_{0.05}$ I		3.89	3.02	9.74
Control		47.6	46.9	80.5
Foliar fertilizers		48.8	47.3	81.2
LSD $_{0.05}$ II		1.05	0.35	n.i.
2014		50.2	49.6	83.2
2015		45.6	44.5	76.8
2016		48.8	47.2	82.7
Mean total		48.2	47.1	80.9

n.i. – non-significant differences

higher in the case of autumn sowing, due to the higher yields of grain and straw.

The grain of the cultivar Bombona had the highest protein content. Most starch was determined in grain of the cultivar Struna, and most fiber appeared in grain of the cultivar Ostka Smolicka (Table 4). The chemical

Table 4

Content of nutrients in grain (% DM)

Variety	Foliar fertilizers	Total protein	Starch	Fiber	Ash
Bombona	–	14.2	59.7	1.62	1.70
	Insol 3	14.6	60.2	1.56	1.73
Ostka Smolicka	–	13.2	60.4	1.96	1.81
	Insol 3	13.6	60.2	1.85	1.89
Struna	–	13.3	63.0	1.64	1.72
	Insol 3	13.7	63.2	1.58	1.80
Interaction IxII		n.i.	n.i.	n.i.	n.i.
Bombona		14.4	60.0	1.59	1.72
Ostka Smolicka		13.4	60.3	1.91	1.85
Struna		13.5	63.1	1.61	1.76
LSD $_{0.05}$ I		0.75	2.74	0.28	n.i.
Control		13.6	61.0	1.74	1.74
Foliar fertilizers		14.0	61.2	1.66	1.81
LSD $_{0.05}$ II		n.i.	n.i.	n.i.	n.i.
2014		13.8	62.8	1.56	1.56
2015		13.1	59.3	1.83	1.96
2016		14.5	61.2	1.71	1.82
Mean total		13.8	61.1	1.70	1.78

n.i. – non-significant differences

composition of grain varied throughout the years of the study. In 2015, grain contained the least protein and starch and the most fiber and ash. The applied foliar fertilizer did not affect the basic chemical composition of the grain.

In a study by Wenda-Piesik et al. (2017), the cultivar Bombona also was characterized by the highest amount of protein in grain. Many 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 with a better technological value is obtained from spring sowing than from autumn. However, in general, these are not very large differences.

Orlik et al. (2005) report that mainly nitrogen fertilization (soil or foliar) causes a significant increase in the percentage content of protein in cereal grain. Bly and Woodard (2003) also indicate the beneficial effect of nitrogen fertilization on the technological quality of wheat grain.

Grain of the cultivar Struna contained most phosphorus and significantly more magnesium than grain of the cultivar Ostka Smolicka. The potassium content in grain of the cultivar Ostka Smolicka was higher than in the cultivar Bombona (Table 5). It was also shown that the content of macroelements

Table 5

Content of macroelements in grain (g kg^{-1} DM)

Variety	Foliar fertilizers	Phosphorus	Potassium	Calcium	Magnesium
Bombona	–	2.39	2.83	0.09	0.75
	Insol 3	2.41	2.80	0.08	0.82
Ostka Smolicka	–	2.41	2.93	0.08	0.68
	Insol 3	2.43	2.91	0.09	0.75
Struna	–	2.56	2.90	0.09	0.89
	Insol 3	2.60	2.86	0.08	0.92
Interaction IxII		n.i.	n.i.	n.i.	n.i.
Bombona		2.40	2.82	0.09	0.79
Ostka Smolicka		2.42	2.92	0.09	0.72
Struna		2.58	2.88	0.09	0.91
LSD $_{0.05}$ I		0.13	0.08	n.i.	0.18
Control		2.45	2.89	0.09	0.77
Foliar fertilizers		2.48	2.86	0.08	0.83
LSD $_{0.05}$ II		n.i.	n.i.	n.i.	0.05
2014		2.56	2.83	0.08	0.78
2015		2.36	2.98	0.06	0.93
2016		2.49	2.80	0.13	0.69
Mean total		2.47	2.87	0.09	0.80

n.i. – non-significant differences

in grain was variable in the years of the study. Under the influence of foliar fertilization, the magnesium content in grain increased. The difference was 0.06 g kg^{-1} in relation to the control. Jarecki et al. (2017), using triple foliar fertilization, obtained an increase in theash and magnesium content in grain compared with the control.

Grain of the cultivar Struna contained more iron and manganese than that of Ostka Smolicka. Most zinc was found in grain of Ostka Smolicka. The content of microelements in grain was variable in the years of the study (Table 6). The foliar fertilizer increased only the iron content in grain compared with the control. Gondek and Gondek (2010) report that the content

Table 6

Content of microelements in grain (mg kg^{-1} DM)

Variety	Foliar fertilizers	Iron	Copper	Zinc	Manganese
Bombona	–	38.6	1.20	11.9	19.3
	Insol 3	39.6	1.22	11.7	19.5
Ostka Smolicka	–	34.2	1.17	12.9	18.6
	Insol 3	36.2	1.16	13.2	18.8
Struna	–	42.6	1.25	11.6	20.4
	Insol 3	43.2	1.28	11.9	20.7
Interaction IxII		n.i.	n.i.	n.i.	n.i.
Bombona		39.1	1.21	11.8	19.4
Ostka Smolicka		35.2	1.17	13.1	18.7
Struna		42.9	1.27	11.8	20.6
LSD $_{0.05}$ I		7.52	n.i.	1.21	1.78
Control		38.5	1.21	12.1	19.4
Foliar fertilizers		39.7	1.22	12.3	19.7
LSD $_{0.05}$ II		1.02	n.i.	n.i.	n.i.
2014		38.9	1.20	10.6	20.6
2015		41.3	1.39	13.8	18.3
2016		37.1	1.04	12.2	19.9
Mean total		39.1	1.21	12.2	19.6

n.i. – non-significant differences

of copper in wheat grain and straw was deficient in terms of feed value, while the content of zinc was within the range of an optimal amount. Jarecki et al. (2017), after applying foliar fertilization three times, showed an increase in the Cu and Zn content in spring wheat grain in comparison with a single foliar fertilizer application and with the control treatment.

CONCLUSIONS

1. The cultivar Struna was characterized by a high ear density per 1m^2, in addition to which it had a high content of starch, phosphorus, magnesium, iron and manganese in grain. Ostka Smolicka was characterized by the highest TGW, high grain yield, SPAD index and high content in potassium and zinc in grain. Grain of the cultivar Bombona had the highest protein content.

2. The application of foliar fertilization increased grain yield about 0.31 t ha^{-1}.

3. The evaluated quantitative and qualitative characteristics of the studied cultivars were varied in the years of the study. The difference in grain yield between 2014 and 2015 was 1.69 t ha^{-1}.

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