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HYBRID WHEAT YIELD AND QUALITY RELATED TO CULTIVATION INTENSITY AND WEATHER CONDITION*

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Abstract

Among the elements of crop cultivation technologies, mineral fertilization and plant protection have a decisive effect on the quantity and quality of wheat grain yield. Therefore, learning the responses of wheat hybrid cultivars introduced into cultivation to the intensity of a cultivation technology should be considered useful. In 2013-2016, a controlled field experiment was carried out, the aim of which was to evaluate the responses of winter wheat hybrid cultivars (Hystar, Hyfi) grown in the low, medium and high input technologies. The growing intensity of a cultivation technology resulted in a significant increase in grain yield and the content of protein, gluten, phosphorus and magnesium, as well as iron, zinc and manganese in grain. Wheat grain from the high input technology was characterized by a higher proportion of the fractions of gliadins and glutenins and their subunits, without differentiating the fractions of albumins and globulins. A lower total precipitation during the grain formation and maturing resulted in a decrease in the grain yield and an increase in grain quality parameters and the content of gluten subunits with the exception of ω gliadins. The cultivar Hystar was characterized by a higher grain yield (by 0.97 t ha^{-1}). The cultivar Hyfi had higher quality parameters with a more favorable proportion of storage proteins and a higher content of phosphorus, magnesium, zinc and manganese in grain.

Keywords: hybrid wheat, cultivation technology, yield, grain quality, protein fractions, chemical composition.

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INTRODUCTION

The yield and technological value of wheat grain are genetically determined and depend on the traits of a cultivar. The environmental factors (temperature, precipitation, soil) and cultivation technologies with different intensity of mineral fertilization and plant protection treatments also are crucial for modification of yield (LLOVERAS et al. 2004, PODOLSKA AND SUŁEK 2012, HORVAT et al. 2015).

An increase in the intensity of a cultivation technology regarding mineral fertilization doses and application regime, in particular nitrogen use, affects not only the grain yield, but also the quantity and quality of protein and gluten and the content of some macro- and micronutrients in grain (GARCÍA-MOLINA, BARRO 2017, WOJTKOWIAK et al. 2018).

Nitrogen affects the content of gluten proteins in grain, differentiating the amount of gluten and the content of gliadins, especially of the ω and γ type and HMW glutenin subunits, and adequate nitrogen application may increase the content of some macro- (Mg) and micronutrients (Zn, Cu, Fe, Mn) in wheat grain (ZHANG et al. 2012, SVEČNJAK et al. 2013).

The yield and quality of wheat grain also depends on the type, doses and chemical composition of the applied plant protection products (BOSTRÖM, FOGELFORS 2002). Redudcing doses of agrichemicals, mainly herbicides, without limiting their effectiveness, usually does not have a significant effect on yielding but may contribute to an increase in wheat grain yield and improvement of its quality (BARROS et al. 2007, BRZOZOWSKA 2008).

Currently, as a result of biological progress in plant breeding, the aim is to obtain wheat cultivars with more favorable qualitative properties of grains, which are nutritionally enriched in the largest possible amount of bioactive substances, but also tolerant to stressful and variable climatic and soil conditions (LONGIN et al. 2012, MÜHLEISEN et al. 2014).

The aim of the study was to assess the effect of the cultivation technology intensity on grain yield volume and quality considering the fractional composition of protein and the content of macro- and micronutrients in hybrid wheat grain. The research hypothesis was that different hybrid wheat cultivation technologies would significantly modify the size and quality of the harvested grain yield.

MATERIAL AND METHODS

A two-factor field experiment was carried out in three seasons, in 2013-2016, at the Experimental Station for Cultivar Testing in Dukla (49°55′ N, 21°68′ E).

The experiment was set up on soil originated from loam (2013/2014) and silty clay (2015/2016), classified as Haplic Cambisol (*CMha*), and clay loam (2014/2015) classified as Gleic Fluvisol (*LVha*) according to WRB (2014). The analysis of soil samples was carried out in an accredited laboratory of the District Chemical-Agricultural Station in Rzeszów, Poland, in accordance with Polish Standards. The physical and chemical properties of the soil assessed before the experiment are given in Table 1.

Table 1

Physical and chemical soil properties before the experiment (0-35 cm)

Traits	Value		
	2013/2014	2014/2015	2015/2016
Soil type	Haplic Cambisol	Gleic Fluvisol	Haplic Cambisol
Soil texture	loam	clay loam	silty clay
pH in KCl	6.81	5.98	6.25
Organic C (g kg^{-1})	12.5	11.0	13.5
P (mg kg^{-1})	80.0	75.3	120.1
K (mg kg^{-1})	170.3	175.6	193.2
Mg (mg kg^{-1})	140.1	120.5	132.1
Fe (mg kg^{-1})	1859	2565	3201
Zn (mg kg^{-1})	18.7	20.1	17.9
Mn (mg kg^{-1})	410.1	205.2	280.6
Cu (mg kg^{-1})	7.1	8.1	6.8

The experiment was set up in a split-plot design with 4 replications. The area of a plot was 16 m^2. The first factor analyzed consisted of three levels of a cultivation technology: low-input, medium-input and high-input. The technology levels differed in doses of NPK fertilization and chemical plant protection preparations (Table 2).

The second factor was composed of two hybrid cultivars of winter wheat: Hystar and Hyfi (breeder Saaten-Union GmbH, France). The tested wheat cultivars were classified in the Common Catalogue of Varieties of Agricultural Plant Species (EU 2007).

In all the years of the experiment, wheat was sown between 21st and 30th of September, at a sowing density of 220 seeds m^{-2}. The plant protection products were applied in accordance with the manufacturer's instructions at the respective wheat development stages. Herbicides were used at the wheat tillering stage, fungicides at the shooting and earing stages, insecticides at the earing stage, and the growth retardant at the shooting stage. Fertilization with nitrogen (NH_4NO_3) was carried out in the spring, after the plant growth started, at a dose of 60 kg ha^{-1}. In the medium- and high--input technologies, nitrogen was additionally applied at the shooting stage (32-33 BBCH) and earing stage (54-56 BBCH). Fertilization with phosphorus

Table 2

Application of fertilizers and plant protection chemicals

Specification		Technology		
		low input	medium input	high input
Fertilizers ($kg\ ha^{-1}$)	N fertilization	60	60 + 40 + 20	60 + 60 +40
	P + K fertilization	40 + 60	60 + 90	80 + 120
* Herbicides ($dm^3\ ha^{-1}$)	mecoprop + MCPA + dicamba	2.0	2.0	–
	pendimethalin + isoproturon	–	–	4.0
	2,4-dichlorophenoxyacetic acid	–	–	3.0
** Insecticides ($dm^3\ ha^{-1}$)	lambda-cyhalothrin	–	0.1	0.1
	dimethoate	–	–	0.5
# Fungicides ($dm^3\ ha^{-1}$)	propiconazole + fenpropidin	–	1.0	1.0
	propiconazole + cyproconazole	–	–	0.5
^ GR ($dm^3\ ha^{-1}$)	trinexapac-ethyl	–	0.2	0.4

* 21–22 BBCH, ** 54–56 BBCH, # 32–33 and 54–56 BBCH, ^ Growth regulator (32–33 BBCH)

($Ca(H_2PO_4)_2$) and potassium (KCl) was applied once under pre-sowing plowing. In all the years and at all the locations, the preceding crop for wheat was winter oilseed rape.

The grain yield of wheat was determinated after harvest. The collected wheat grain samples were subjected to laboratory analysis, and the protein content (ICC 105/2, 1994) and wet gluten content in the grain (ICC 155, 1994) were determined, according to the standards. The quantitative and qualitative characteristics of protein in the grain were determined with the RP-HPLC technique according to Wieser et al. (1998) and Konopka et al. (2007). The content of albumins and globulins, gliadins and glutenins was analyzed. Albumins were extracted with the use of distilled water, globulins with a mixture of NaCl and $HKNaPO_4$, gliadins with 60% ethanol, and glutenins in the mixture consisting of 50% propanol-1 + 2 m of urea + tris-HCl and 1 DTE under nitrogen. Detection was carried out at a wavelength of 210 µm. The results were analyzed with the use of a computer program HPLC 3D ChemStation and was presented in mAU s^{-1} (milliabsorbance units).

Macro- and micronutrients were determined at the Laboratory of the Faculty of Biology and Agriculture, the University of Rzeszow. To determine macro- and microelements, plant samples were mineralized in a mixture of concentrated acids HNO_3:$HClO_4$:HS_2O_4 in the ratio 20:5:1, in an open system in a Tecator heating block. The content of Ca, K, Mg, Zn, Mn, Cu, Fe was determined in the mineralisates with atomic absorption spectroscopy (FAAS), using a Hitachi Z-2000 apparatus (Tokyo, Japan), whereas P was determined by colorimetry, using a UV-VIS Schimadzu spectrophotometer (Kyoto, Japan), according to the vanadate-molybdate method. The grain yield from the plots was expressed per 1 ha at 15% moisture.

Statistical analyses

The results of the study were statistically analyzed with the analysis of variance (ANOVA), using the statistical software Analwar-5.1FR and Statistica 9.0 (StatSoft, Tulsa, USA). Significance of differences between treatments was verified by the Tukey's test (LSD), at a significance level $\alpha = 0.05$.

Weather conditions

The weather conditions are given according to the data of the Experimental Station for Cultivar Testing in Dukla. The precipitation totals were more varied during the study years than the mean air temperatures (Table 3). During the winter dormancy period, the lowest air temp. (-2.6°C)

Table 3

Weather conditions over the wheat growing period

Year	The period of grain formation (month/ten-day period)						D	S/H
	June			July				
	1st	2nd	3rd	1st	2nd	3rd		
Temperature (°C)								
2013/2014	14.4	19.0	18.0	23.0	18.7	19.8	18.8	7.0
2014/2015	15.0	19.4	17.2	17.8	16.5	20.1	17.7	7.2
2015/2016	15.5	14.9	15.9	18.6	18.8	20.4	17.4	8.4
1960–2012	16.2	18.3	17.6	19.1	18.6	21.0	18.5	6.9
Precipitation (mm)								
2013/2014	44.0	45.0	82.6	20.1	55.3	40.1	287.1	678.4
2014/2015	35.9	38.3	52.9	10.2	30.6	12.6	180.5	642.0
2015/2016	5.6	12.3	45.6	68.2	110.1	29.3	271.1	847.5
1960-2012	38.9	35.6	62.3	45.3	75.2	45.6	302.9	783.5

D – mean/sum (from decade), S/H – mean/sum (from sowing to harvest)

was recorded in January 2016. In the period from wheat sowing to harvesting, the season 2015/2016 was the warmest of the years of the study, with the mean temperature higher than the long-term temp. by 1.5°C. However, in the season of forming and ripening grains, average ten-day temperatures were lower than the long-term records, and the rainfall shortage in the Juny-July period was the highest in the season 2014/2015, when it equalled 122.4 mm. However, in that season, during grain formation and maturation, mean ten-day temperatures were lower than the long-term temperatures, and the rainfall deficit in the June-July period was the highest in the season 2014/2015, when it equalled 122.4 mm. In the season 2015/2016, the amount of rainfall in the growing season was higher by 64.0 mm compared to the long-term rainfall total.

RESULTS AND DISCUSSION

Wheat grain yield was significantly dependent on the cultivation technology input, cultivars, years of the study and interactions between experimental factors (Figure 1). The highest grain yield was obtained for the high

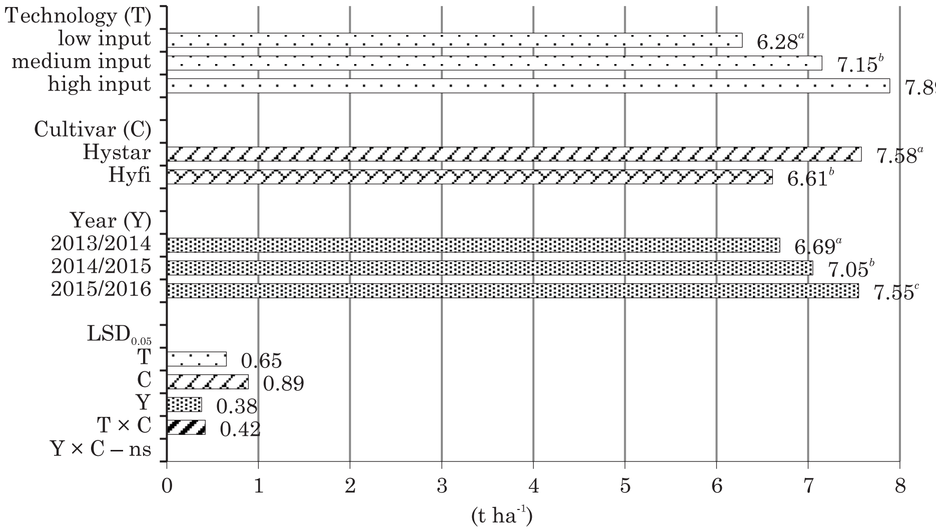

Fig. 1. Grain yield of wheat cultivars depending on the technology and years. Average values for each factor marked with different letters in a column differ significantly ($P < 0.05$)

input, lower for the medium input and the lowest for the low input technology. Differences in grain yield between the high input technology and the medium and low input technologies reached 9.4% and 20.4%, and were statistically significant. There was also a significant difference in the yield between the medium and low input technologies, which equalled 0.87 t ha^{-1}. Podolska and Sułek (2012), in their comparison of yields of wheat depending on the intensity of a technology, proved that the yield ranged from 6.4 to 7.8 t ha^{-1}. Litke et al. (2018) showed a significant increase in wheat yield up to a nitrogen dose of 180 kg ha^{-1}, especially for conventional cultivation compared with reduced one. According to Lloveras et al. (2004), the level of wheat yield is determined by an appropriate cultivar genotype and sufficient soil moisture. Cultivar Hystar gave significantly higher yields than Hyfi, and the difference in yield was 12.8%. The effect of interaction between cultivars and levels of the cultivation technology on the quantity of grain yield was found. Both Hystar and Hyfi responded similarly to an increase in the cultivation intensity. The highest grain yield was recorded in the season 2015/2016, when the amount of precipitation in the growing season was 847.5 mm. Significantly lower yields were harvested from wheat in the first and second growing seasons, when the amount of rainfall was lower than the long-term mean by 105.1 and 141.5 mm, respectively.

An increase in the cultivation intensity, and especially an increase in nitrogen fertilization, improves to a certain level the technological value of wheat grain, mainly through the increase in the protein and gluten content (Litke et al. 2018). Significantly more protein and gluten were obtained in grain from the high input technology compared with the low input technology. The values of these parameters did not differ statistically between the medium and high input technologies (Table 4).

Table 4

Chemical properties and composition of proteins in grain

Factors	Protein (g kg^{-1})	Gluten (%)	Albumins globulins (mAU s^{-1})	Gliadins (mAU s^{-1})	Glutenins (mAU s^{-1})	Gli/Glu
Technology (T)						
Low input	114^{a}	24.5^{a}	11.7^{a}	24.3^{a}	17.6^{a}	1.38^{a}
Medium input	131^{b}	27.3^{b}	12.1^{a}	26.6^{a}	21.9^{a}	1.21^{a}
High input	139^{b}	28.3^{b}	12.3^{a}	31.6^{b}	24.6^{b}	1.28^{a}
Cultivar (C)						
Hystar	121^{a}	25.1^{a}	12.1^{a}	24.9^{a}	19.4^{a}	1.28^{a}
Hyfi	135^{b}	28.3^{b}	11.9^{a}	30.1^{b}	23.3^{b}	1.29^{a}
Year (Y)						
2013/2014	133^{a}	27.1^{a}	12.4^{a}	26.3^{a}	19.8^{a}	1.33^{a}
2014/2015	137^{a}	28.8^{a}	13.4^{a}	32.6^{b}	27.1^{b}	1.20^{a}
2015/2016	115^{b}	24.1^{b}	10.2^{b}	23.5^{a}	17.2^{a}	1.37^{a}
$LSD_{0.05}$						
T	14	2.0	ns	1.8	3.2	ns
C	10	1.5	ns	2.8	2.1	ns
Y	12	2.1	1.8	4.0	4.2	ns
T × C	11	1.4	ns	2.5	3.1	ns
Y × C	ns	1.8	ns	2.3	1.2	ns

Average values for each factor marked with different letters in a column differ significantly ($P < 0.05$); Gli/Glu – ratio gliadins/glutenins

According to Šip et al. (2013), a higher level of cultivation technology, regardless of the wheat cultivar, clearly stimulates the improvement of grain quality parameters. López-Bellido et al. (1998) maintain that the combination of the genetic characteristics of a cultivar and the agronomic and environmental conditions and their interaction affect protein and gluten values in the grain. In the present study, significant interactions of cultivation technology and cultivar were obtained for the protein and gluten content, and the interactions between study year and cultivar were proven only for gluten. Cultivar Hyfi had a significantly higher protein and gluten content (by 14 g kg^{-1} and 3.2%) than cv. Hystar, thus not deviating from the values of these parameters given by ROZBICKI et al. (2015). Grain of Hystar and Hyfi collected during the growing season of 2015/2016 with the highest amount of precipitation (especially from the 1st to 20th of July) and moderate thermal conditions was characterized by a lower content of protein and gluten.

The experimental factors also determined the protein fractional composition. A significant increase in gliadins and glutenins was found in the grain from high input technology as compared with the other technology variants (Table 5). The difference in the accumulation of these fractions in grain from the high input technology in relation to the medium and low input ones was 15.8% and 23.1% for gliadins and 11.0% and 28.5% for glutenins. In the studies by FUERTES-MENDIZÁBAL et al. (2010) and GARCIA-MOLINA and BARRO (2017) an increase in the content of gliadins and glutenins in wheat grain

Table 5

Content of subunits of storage proteins in grain

Factors	Gliadins			Glutenins		H/L
	α/β	*γ*	*ω*	HMW	LMW	
	(mAU s^{-1})					
Technology (T)						
Low input	13.4^{a}	7.4^{a}	3.5^{a}	3.6^{a}	14.0^{a}	0.26^{a}
Medium input	14.5^{a}	9.0^{b}	3.2^{a}	5.4^{b}	16.6^{b}	0.32^{a}
High input	17.3^{b}	10.5^{c}	3.9^{b}	6.0^{b}	18.7^{b}	0.32^{a}
Cultivar (C)						
Hystar	13.1^{a}	8.5^{a}	3.3^{a}	4.5^{a}	14.9^{a}	0.30^{a}
Hyfi	16.9^{b}	9.5^{b}	3.7^{a}	5.5^{b}	17.8^{b}	0.31^{a}
Year (Y)						
2013/2014	14.3^{a}	9.0^{a}	3.0^{a}	4.6^{a}	15.2^{a}	0.30^{a}
2014/2015	17.5^{b}	12.1^{b}	3.0^{a}	6.7^{b}	20.4^{b}	0.33^{a}
2015/2016	13.1^{a}	6.0^{c}	4.4^{b}	3.6^{a}	13.6^{a}	0.26^{a}
$LSD_{0.05}$						
T	2.1	0.8	ns	1.0	2.3	ns
C	2.9	0.6	ns	0.7	2.0	ns
Y	2.5	1.2	1.8	1.5	2.9	ns
T × C	1.5	0.7	ns	0.8	2.5	ns
Y × C	1.8	1.0	ns	1.2	1.8	ns

Average values for each factor marked with different letters in a column differ significantly ($P < 0.05$); HMW – high molecular weight, LMW – low molecular weight, H/L – ratio HMW/ /LMW.

was noted under the influence of increasing nitrogen doses. The technology and the cultivar did not differentiate the content of albumins and globulins (Šramkova et al. 2009). The applied cultivation technologies differentiated the content of protein subunits of monomeric gliadins and polymeric glutenins (Table 5). There were no significance differences in the content of gliadin

Table 6

Macroelement content in grain

Factors	Phosphorus	Potassium	Calcium	Magnesium
	(g kg^{-1} DM)			
Technology (T)				
Low input	3.35^{a}	4.23^{a}	0.45^{a}	0.85^{a}
Medium input	3.65^{a}	4.38^{a}	0.38^{a}	0.90^{a}
High input	3.78^{b}	4.11^{a}	0.40^{a}	1.10^{b}
Cultivar (C)				
Hystar	3.48^{a}	4.27^{a}	0.39^{a}	0.85^{a}
Hyfi	3.70^{b}	4.20^{a}	0.43^{a}	1.05^{b}
Year (Y)				
2013/2014	3.42^{a}	4.16^{a}	0.44^{a}	0.92^{a}
2014/2015	3.80^{b}	4.35^{b}	0.37^{a}	1.05^{b}
2015/2016	3.56^{a}	4.20^{a}	0.41^{a}	0.89^{a}
$LSD_{0.05}$				
T	0.09	ns	ns	0.15
C	0.15	ns	ns	0.12
Y	0.19	0.10	ns	0.10
T × C	ns	ns	ns	ns
Y × C	ns	ns	ns	ns

Average values for each factor marked with different letters in a column differ significantly ($P < 0.05$).

and glutenin subunits for the medium and high input technologies. Similarly to the results reported by Ramírez-Wong et al. (2014), significantly most α/β, γ and ω gliadins and HMW and LMW glutenins were found after the use of the high input technology (180 kg N·ha^{-1}) compared with the low-input ones (60 kg N ha^{-1}). The ratios of Gli/Glu and HMW/LMW fractions of glutenins were not significantly differentiated by the experimental factors, reaching 1.29 and 0.30 on average (Tables 4, 5). Horvat et al. (2015) showed that the Gli/Glu ratio ranged from 1.35 to 2.09 and depended on the environmental conditions and the genotype of wheat cultivars. According to Ramírez-Wong et al. (2014), a more favorable HMW/LMW glutenin ratio (0.49) was obtained after the application of nitrogen in the form of urea and simultaneous wheat irrigation. As well as having a lower content of albumins and globulins, grain of the cultivar Hyfi contained significantly more gliadins and glutenins and their subunits than grains of cv. Hystar. As for the content of protein fractions and their subunits, interactions of a technology with a cultivar were shown, in addition to some variation in the years of the study. The cultivar with year interaction indicates a significant effect of environmental conditions on the content of gliadins and glutenins and their subunits, as implicated by Fuertes-Mendizábal et al. (2010) and Horvat et al. (2015). A higher content of protein fractions and their subunits in the grain was shown in the season 2014/2015, with a ten-day total precipitation of 180.5 mm and an average ten-day temp. of 17.7°C in June and July.

Increasing the intensity of a cultivation technology contributed to a significant increase in phosphorus and magnesium in grain (Table 6). In the high input technology, the content of phosphorus and magnesium in grain increased by 0.43 and by 0.25 g kg^{-1}, respectively, in relation to the low input technology. An increase in the phosphorus and potassium content in the grain of wheat cultivars in the intensive technology with a nitrogen dose of 200 kg·ha^{-1} was also demonstrated by Wojtkowiak et al. (2018). Gondek and Gondek (2010), while conducting a study with NPK fertilization of spring wheat, proved the effect of increasing Mg content only for the wheat straw, and no such response was observed for the grain. In the present study, there was no significant effect of the experimental factors (technology and cultivar) on the potassium and calcium content in the wheat grain, and on the interaction of experimental factors. Brzozowska (2008) obtained considerable variation in the macronutrient content in wheat grain in the study years, noting an increase in potassium in the wheat grain fertilized with a nitrogen dose of 135 kg ha^{-1}, where 25 kg N ha^{-1} was used by foliar application. The wheat grain harvested in the season 2014/2015 was characterized by a higher concentration of phosphorus, potassium and magnesium. Grain of cv. Hyfi was distinguished by a significantly higher content of phosphorus and magnesium in relation to cv. Hystar.

However, the content of potassium and calcium was not significantly modified by the varietal factor. The average micronutrient content in the grain of wheat cultivars was close to the amount of phosphorus (3.59 g kg^{-1}) and potassium (4.24 g kg^{-1}) found in the study by Wang et al. (2016) as well as the content of calcium (0.41 g kg^{-1}) and magnesium (0.95 g·kg^{-1}) determined in by Wiśniowska-Kielian and Klima (2007).

The increased cultivation technology intensity caused an increase in the content of iron, zinc and manganese in the dry weight of grain (Table 7). In the high input technology, the Fe, Zn and Mn content in the grain increased by 1.80, 6.20 and 14.44 mg kg^{-1}, respectively, in relation to the low input technology. Also Svečnjak et al. (2013) showed a significant increase in the content of these elements in the wheat grain for a nitrogen dose of 194 kg ha^{-1} as compared with 67 kg ha^{-1}, which on average amounted to 5.10 mg kg^{-1} for iron, 3.50 mg kg^{-1} for zinc and 9.10 mg kg^{-1} for manganese.

Table 7

Microelement content in grain

Factors	Iron	Copper	Zinc	Manganese
	(mg kg^{-1} DM)			
Technology (T)				
Low input	42.20^{a}	2.21^{a}	31.25^{a}	24.56^{a}
Medium input	43.10^{ab}	2.48^{a}	34.29^{b}	28.45^{a}
High input	44.00^{b}	2.35^{a}	37.45^{c}	39.00^{b}
Cultivar (C)				
Hystar	42.30^{a}	2.45^{a}	32.52^{a}	27.12^{a}
Hyfi	43.90^{a}	2.25^{a}	36.13^{b}	34.21^{b}
Year (Y)				
2013/2014	42.61^{a}	2.35^{a}	34.00^{a}	28.10^{a}
2014/2015	44.56^{b}	2.41^{a}	36.10^{b}	34.20^{b}
2015/2016	42.12^{a}	2.28^{a}	32.90^{a}	29.70^{a}
$LSD_{0.05}$				
T	1.70	ns	2.85	11.20
C	ns	ns	3.00	5.08
Y	1.51	ns	1.92	3.81
T × C	ns	ns	ns	ns
Y × C	ns	ns	ns	ns

Average values for each factor marked with different letters in a column differ significantly ($P < 0.05$)

GAO et al. (2012) obtained an increase in the Fe and Zn concentrations in grain as a result of an early date of sowing the wheat, including an interaction of the soil type with the years of the study. In the present study, no effect of interactions between the experimental factors and the content of micronutrients in wheat grain was demonstrated. However, significantly more Zn, Mn and Fe in grain were found in the season 2015/2016, which was characterized by less rainfall and moderate temperature during the wheat flowering period (FICCO et al. 2009, GAO et al. 2012). The content of zinc and manganese in the cv. Hyfi grain was significant higher than the values determined in Hystar. The effect of a cultivar on the content of iron and copper was been demonstrated. The average amount of Fe (43.10 mg kg^{-1}) and Zn (34.33 mg kg^{-1}) in the grain of hybrid wheat cultivars was similar to the values found by ZHANG et al. (2010). The average amount of Mn (30.67 mg kg^{-1}) was higher and that of Cu (2.33 mg kg^{-1}) was similar to the content found by JANKOWSKI et al. (2016) in wheat grain fertilized by foliar application.

CONCLUSIONS

1. The high input technology effected a significant increase in grain yield and the content of protein, gluten, phosphorus and magnesium, as well as iron, zinc and manganese, in grain.

2. Technology intensity did not affect the content of albumins and globulins in grain resulting in a higher proportion of gliadin and glutenin fractions and their subunits, and the qualitative characteristics and fractional composition of protein in the grain were dependent on the weather conditions during the wheat growing period.

3. The cultivar Hyfi was characterized by a more favorable proprotion of storage proteins and a higher content of phosphorus, magnesium, zinc and manganese in the grain, and the cultivar Hystar was characterized by a higher grain yield.

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