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EFFECT OF INTENSITY OF AGRICULTURAL TECHNIQUES AND GRAIN STORAGE ON TECHNOLOGICAL QUALITY OF WINTER WHEAT* PART I. QUALITY TRAITS OF GRAIN AND FLOUR

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Abstract. The paper presents quality evaluation of grain and flour from winter wheat cv. Bogatka, cultivated in the years 2007-2009 on brown soil, of the good wheat complex. Experimental factors included: plant protection (extensive, intensive), nitrogen fertilization (60, 100, 140, 180 kg N·ha^{-1}), time of harvest (optimum and delayed for 2 weeks) as well as the time of grain storage. Quality evaluation of the grain was carried out directly after harvest and after its half-year storage. The following parameters were determined: weight of one thousand grains, hectoliter weight, vitreousness and grain mealiness as well as the content and quality of gluten. Intensification of the plant protection level did not significantly affect hectoliter weight, grain vitreousness and gluten extensibility, however its content and a thousand grain weight increased. Increase of nitrogen fertilization affected the increase of hectoliter weight and its vitreousness, as well as the amount of washed gluten. Gluten extensibility remained constant. Harvest delay resulted in the deterioration of hectoliter weight and its vitreousness as well as in the decrease of gluten efficiency, however its extensibility did not change.

Key words: gluten, gluten extensibility, grain vitreousness, hectoliter weight, level of plant protection, nitrogen fertilization, time of harvest

INTRODUCTION

Great part of wheat in the sowing structure is mainly connected with the yield-forming potential of this species and with the possibility to use the grain not only for feed purposes, but also in the milling industry and baking industry [Podolska *et al.* 2004, 2005]. Wheat grain intended for consumption purposes must be characterized by high technological quality. The most important factors of agricultural techniques which affect grain quality should include: level and time of nitrogen fertilization and

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protection against weeds, diseases and pests [Podolska *et al.* 2004, 2005, Cacak-Pietrzak *et al.* 2005, Miś 2005, Podolska 2008]. A very important element affecting the quality are also weather conditions at the time of harvest. Delay in the harvest time during rainfall promotes occurrence of diseases and yield losses, which oscillate around 15%. Grain quality also deteriorates as a result of the start of enzymatic processes leading to sprouting [Rothkaehl and Kosiewicz 1998, Kościelniak and Rothkaehl 2000, Podolska and Sułek 2002]. Technological properties of grains are also affected by the method and time of storage [Podolska i Sułek 2002]. Grain intended for storage should be properly aired and cooled to optimum temperature and moisture. Storing too moist grain results in irreversible quality deterioration and large losses, leading to its disqualification [Janowicz 2007]. In the research it was assumed that quality parameters of grain and flour are determined by correlative effect of nitrogen fertilization, intensity of plant protection against agrophages, time of harvest and time of grain storage. It was expected that with application of high nitrogen fertilization and intensive chemical protection, the delay of the time of harvest and half-year storage would not affect substantial deterioration of parameters determining the quality of grain and flour.

The aim of the research was determination of the effect of intensity of plant protection against agrophages, nitrogen fertilization, time of harvest and time of grain storage on the quality and quantity of washed gluten, weight of one thousand grains, hectoliter weight and grain vitreousness of winter wheat cv. Bogatka.

MATERIAL AND METHODS

The field experiment was carried out at the Eperimental Station of Cultivar Testing in Chrząstowo near Nakło (53°09’ N; 17°35’ E). The source material was obtained from a 3-year, three-factorial field experiment conducted in the years 2007-2009. The experiment was set up in a mixed randomized and split-block design in 3 replications. The area of the plot for harvest was 15 m^2. Experimental factors included:

A – level of plant protection: extensive A_1 – dressing the seed material (Oxafun T 75 DS) and weed control (Aminopielik Tercet 500 SL – 1.9 $dm^3 \cdot ha^{-1}$); intensive A_2 – dressing the grain (Oxafun T 75 DS), application of herbicides (Cougar 600 C – 1.5 $dm^3 \cdot ha^{-1}$, Aminopielik Tercet 500 SL 1.9 $dm^3 \cdot ha^1$), fungicides (Acanto 250 SC – 1.0 $dm^3 \cdot ha^{-1}$, Tilt Plus – 1.0 $dm^3 \cdot ha^{-1}$, Amistar – 0.6 $dm^3 \cdot ha^{-1}$) and insecticides (Karate Zeon 050 CS 1.0 $dm^3 \cdot ha^{-1}$, Talstar 00 EC – 0.6 $dm^3 \cdot ha^{-1}$) and retardant (Moddus 250 EC – 0.4 $dm^3 \cdot ha^{-1}$),

B – nitrogen fertilization: B_1 – 60, B_2 – 100, B_3 – 140, B_4 – 180 kg $N \cdot ha^{-1}$,

C – time of harvest: C_1 – at the stage of complete maturity, C_2 – delayed for 2 weeks,

D – grain evaluation conducted directly after the harvest and after half-year storage.

The cultivated winter wheat was of Bogatka cultivar. It is a bread wheat cultivar with a very high weight of one thousand grains, quite good grain uniformity, quite low hectoliter weight, average resistance to sprouting in spike, quite high protein content and high or very high gluten content. The wheat was sown in the third decade of September on soil included in the good wheat complex. The forecrop constituted annual papilionaceous plants. Before sowing the following fertilization was applied: P – 26 $kg \cdot ha^{-1}$, K – 50 $kg \cdot ha^{-1}$, and nitrogen fertilization according to the scheme presented in Table 1.

Table 1. Dates and rates of nitrogen application, kg N·ha^{-1}
Tabela 1. Terminy i dawki stosowania azotu, kg N·ha^{-1}

Fertilization Nawożenie	Resumption of growth Wznowienie wegetacji	Phase 3 of internode Faza 3 międzywęźla BBCH-23	Stem elongation Strzelanie w źdźbło BBCH-39	End of heading Po kłoszeniu BBCH-59
60	35	15	5	5
100	55	30	8	7
140	75	45	10	10
180	95	60	13	12

Fungicides were applied together with foliar nitrogen fertilization, and in justified cases additional spraying with insecticides and fungicides was applied. Herbicides were applied postemergence in autumn and in spring at the time of full wheat tillering, according to producer's recommendations. Wheat was harvested on 27-30 July at the stage of its optimum ripeness, and after 2 weeks a delayed harvest was carried out. The harvest was conducted with the use of a plot combine harvester. Wheat grain was stored in 10-14% of its moisture, with air temperature 12-20°C. Samples for laboratory tests were collected from each plot separately, next in four replications a collective sample was formed, and with the use of a separator two laboratory samples. Laboratory tests were carried out on two dates: 3 weeks and 6 months after the harvest. The effect of experimental factors on the following parameters was determined:

- weight of one thousand grains – determined according to PN-68/R-74017 [1968],
- hectoliter weight – determined according to PN-ISO 7971-2 [1998],
- grain vitreousness and mealiness – 50 grains were cut at the same time and the number of grains with completely or partly vitreous endosperm on the surface of the section was calculated – according to PN-70/R-74008 [1970],
- quality and quantity of washed gluten in flour – a dough was prepared which was in accordance with standard requirements PN-77/A-74041 [1977], PN-A/74043 [1994] equivalent to ISO standard, test of gluten quality was carried out with an automatic glutometer produced by ZBPP Sadkiewicz.

Obtained numerical material was elaborated statistically with the use of analysis of variance of traits in the design: constant factors, years as replications. Significance of differences was evaluated with Tukey test. Calculations were carried out with the use of FR-ANALWAR-3.2 package, based on the Microsoft Excel spread sheet.

Weather conditions in the years 2007-2009 in the growing season of winter wheat were highly diversified (Table 2). The wheat in the first year of experiment was harvested at the stage of complete maturity of the grain, at optimum time, at the end of July. In the second year, in May and June, there was drought. Between the optimum time of harvest (the end of July) and the delayed harvest there occurred substantial rainfall. In the third year, as a result of long drought, the wheat formed spikes much faster than in previous years, and the heavy rains in the second half of May (267.1 mm) and low air temperature in June created favorable conditions for the development of fungal diseases. Optimum harvest was carried out in the last week of July.

Table 2. Characteristics of weather conditions
Tabela 2. Charakterystyka warunków pogodowych

Climatic factor Czynnik klimatyczny	Month – Miesiąc	Year – Rok				Mean Średnia 1965-2007
		2006/2007	2007/2008	2008/2009	mean średnia	
Rainfall – Opady mm	September – wrzesień	30.5	39.5	27.3	32.4	45.6
	October – październik	21.6	22.6	57.9	34.0	39.1
	November – listopad	26.3	27.3	22.1	25.2	33.0
	December – grudzień	32.3	35.9	33.5	33.9	37.4
	January – styczeń	12.5	57.7	14.5	28.2	30.1
	February – luty	22.4	12.1	27.4	20.6	23.7
	March – marzec	23.0	53.5	43.0	39.8	34.1
	April – kwiecień	31.1	40.0	0.9	24.0	31.8
	May – maj	9.1	13.8	77.7	33.5	52.3
	June – czerwiec	8.7	19.6	106.8	45.0	65.2
	July – lipiec	103.1	65.0	96.8	88.3	73.9
	August – sierpień	62.9	101.3	69.9	78.0	53.5
Temperature – Temperatura °C	September – wrzesień	14.7	12.7	12.7	13.4	13.3
	October – październik	7.9	7.2	8.5	7.9	8.7
	November – listopad	3.8	1.7	4.3	3.3	4.2
	December – grudzień	0.6	0.9	0.5	0.7	-0.1
	January – styczeń	-1.2	0.7	-3.5	-1.3	-2.0
	February – luty	-6.5	3.3	-1.1	-1.4	-0.9
	March – marzec	2.5	3.1	2.7	2.8	2.6
	April – kwiecień	7.3	8.0	10.6	8.6	7.6
	May – maj	10.1	13.7	12.5	12.1	13.4
	June – czerwiec	13.2	17.3	14.9	15.1	16.9
	July – lipiec	18.1	18.9	18.8	18.6	18.8
	August – sierpień	16.9	17.7	18.1	17.6	18.2

RESULTS AND DISCUSSION

Invasion of wheat plants by diseases most often reduces assimilation and increases respiration, which results in deficiency of assimilates stored in the grain. In consequence, what is harvested is grain which is poorly formed and not uniform. It may be the reason of its low technological quality [Ceglińska *et al.* 2002]. In the presented research, more intensive plant protection against agrophages increased the weight of one thousand grains of winter wheat by 2.5% (Table 3). Also Khan *et al.* [2003], Narkiewicz-Jodko *et al.* [2007], as well as Mularczyk *et al.* [2010], proved increase of the weight of 1000 grains under the effect of a more intensive protection. In own research, higher than 60 kg·ha^{-1} nitrogen fertilization did not cause change in the weight of one thousand grains, it was approximately 51 g. Cacak-Pietrzak *et al.* [2005], as well as Podolska [2008], also did not find the effect of nitrogen rate on the weight of 1000 grains. However, intensification of nitrogen fertilization increased hectoliter weight, but only to the rate of 140 kg N·ha^{-1} (Table 4). Cacak-Pietrzak *et al.* [2005], while using diversified fertilization, did not find the effect of nitrogen on hectoliter weight. Delayed harvest causes, among others, deterioration of hectoliter weight [Witkowska and Witkowski 2000, Ceglińska *et al.* 2002, Ellmann *et al.* 2005]. In own research, it was found that harvest delay affected the increase of the weight of one thousand grains and slightly, by 2.9 kg·hl^{-1}, the decrease of hectoliter weight. It was proved, similarly to Janowicz [2007], that grain properly stored does not change the weight of one thousand grains or hectoliter weight. However, Podolska and Sułek [2002] found that these parameters depend on the method and time of storage.

Table 3. Thousand grain weight, g
Tabela 3. Masa tysiąca ziaren, g

Factor – Czynnik		Level of nitrogen fertilization (B) Poziom nawożenia azotem kg N·ha^{-1}				Mean Średnia
level of plant protection (A) poziom ochrony roślin	time of harvest (C) termin zbioru	60	100	140	180	
Extensive – Ekstensywny	optimum – optymalny	49.8	51.5	48.8	49.9	50.0
	delayed – opóźniony	51.5	50.3	50.7	51.3	51.0
Mean – Średnia		50.7	50.9	49.8	50.6	50.5
Intensive – Intensywny	optimum – optymalny	50.2	51.3	51.8	51.7	51.3
	delayed – opóźniony	52.0	52.1	53.3	52.1	52.4
Mean – Średnia		51.1	51.7	52.6	51.9	51.8
Mean – Średnia	optimum – optymalny	50.0	51.4	50.3	50.8	50.6
	delayed – opóźniony	51.7	51.2	52.0	51.9	51.7
Mean – Średnia		50.9	51.3	51.2	51.3	51.2
$LSD_{0.05}$ – $NIR_{0,05}$		A 0.41 C 0.82				

Table 4. Hectoliter weight, kg·hl^{-1}
Tabela 4. Gęstość ziarna w stanie zsypnym, kg·hl^{-1}

Factor – Czynnik		Level of nitrogen fertilization (B) Poziom nawożenia azotem kg N·ha^{-1}				Mean Średnia
level of plant protection (A) poziom ochrony roślin	time of harvest (C) termin zbioru	60	100	140	180	
Extensive – Ekstensywny	optimum – optymalny	77.7	78.6	78.2	78.9	78.4
	delayed – opóźniony	75.5	75.1	76.4	75.7	75.7
Mean – Średnia		76.6	76.9	77.3	77.3	77.0
Intensive – Intensywny	optimum – optymalny	78.6	79.3	79.3	79.2	79.1
	delayed – opóźniony	75.5	75.9	76.4	76.1	76.0
Mean – Średnia		77.0	77.6	77.8	77.6	77.5
Mean – Średnia	optimum – optymalny	78.1	79.0	78.8	79.1	78.7
	delayed – opóźniony	75.5	75.5	76.4	75.9	75.8
Mean – Średnia		76.8	77.2	77.6	77.5	77.3
$LSD_{0.05}$ – $NIR_{0,05}$		B 0.04 C 0.01				

Vitrousness and mealiness of the grain are connected with its colour and hardness. More vitreous grains indicate a better technological quality, and such wheat usually contains more glutenous proteins determining the baking quality [Daniel and Triboi 2000, Miś 2005, Podolska 2008]. In own research, similarly to Cacak-Pietrzak *et al.* [2005], no effect of the level of plant protection on grain vitreousness was found (Table

5). Podolska *et al.* [2004], however, intensifying plant protection against agrophages, obtained improvement of this parameter. In the conducted experiment, the number of vitreous grains increased under the effect of increased nitrogen fertilization, harvest in due time and storage time. Substantial improvement of grain vitreousness occurred after application of only 100 kg N·ha^{-1}, compared with 60 kg N·ha^{-1}, and after increasing the rate to 180 kg·ha^{-1} the proportion of vitreous grains increased from 25% up to 75%. In the research of Cacak-Pietrzak *et al.* [2005], the number of vitreous grains increased significantly after increasing the nitrogen rate from 90 to 120 kg·ha^{-1}. Fertilization on the level of 150 kg N·ha^{-1} did not cause statistically significant changes in this trait. Ceglińska *et al.* [2002] also proved that together with the increase of the rate of the applied nitrogen, the content of vitreous grains increases. Delay of harvest for 2 weeks resulted in the decrease of grain vitreousness by 44%. Research of other authors [Dominquez and Cejudo 1996, Podolska *et al.* 2004] also proves that harvest delay decreases the number of vitreous grains.

Table 5. Grain vitreousness, %
Tabela 5. Szklistość ziarna, %

Factor – Czynnik		Time of harvest – Termin zbioru (C)		
level of nitrogen fertilization (B) poziom nawożenia azotem kg N·ha^{-1}	storage time (D) czas przechowywania	optimum optymalny	delayed opóźniony	mean średnia
60	not stored – nie przechowywane	29.8	16.6	23.2
	stored – przechowywane	30.0	16.4	23.2
Mean – Średnia		29.9	16.5	23.2
100	not stored – nie przechowywane	41.7	21.2	31.4
	stored – przechowywane	45.8	24.4	35.1
Mean – Średnia		43.7	22.8	33.3
140	not stored – nie przechowywane	46.4	24.3	35.4
	stored – przechowywane	49.2	26.7	37.9
Mean – Średnia		47.8	25.5	36.7
180	not stored – nie przechowywane	51.2	29.0	65.6
	stored – przechowywane	63.6	42.0	84.6
Mean – Średnia		57.4	35.5	75.1
Mean – Średnia	not stored – nie przechowywane	42.3	22.8	38.9
	stored – przechowywane	47.1	27.4	45.2
Mean – Średnia		44.7	25.1	42.1
$LSD_{0.05}$ – $NIR_{0,05}$		B 10.09	C 11.05	D 3.5

Gluten determines the bread volume, and its quality determines dough elasticity [Podolska *et al.* 2005]. High nitrogen fertilization is essential to obtain grain with a proper quantity and quality of gluten [Peltonen and Virtanen 1994, Kościelniak and Rothkaehl 2000]. In the conducted experiment, quantity of washed gluten with the nitrogen rate of 60 kg·ha^{-1} was 21.7%, and increased to 30.8% after application of 180 kg N·ha^{-1} (Table 6). In the research of Cacak-Pietrzak *et al.* [2005], quantity of washed gluten also increased with the increase of the level of nitrogen fertilization, but the differences were found between variants 90 and 150 kg N·ha^{-1}. Effective plant protection against diseases, pests and weeds also determines its quantity [Podolska *et al.* 2004, Stankowski *et al.* 2004, Wyczling *et al.* 2005, Stankowski and Rutkowska 2006].

Similarly, in the author's research, intensive protection caused increase of gluten efficiency by 5.5%. Harvest delay for two weeks decreased its efficiency by 4%. In the research of Rothkaehl *et al.* [1998], Witkowska *et al.* [2000], Podolska *et al.* [2004, 2005] as well as Ellmann [2005], harvest delay in bad weather conditions caused decrease of gluten content in the obtained grain.

Good quality gluten should have low extensibility, i.e. below 10 mm [Knapowski and Ralcewicz 2004, Cacak-Pietrzak 2005]. In the conducted research, gluten extensibility did not change significantly under the effect of the applied factors, and remained on average on a very good level of 4.1 mm (tab. 7). However, under the effect of nitrogen fertilization, tendency towards slight changes was found, similarly to the research of Gianibelli and Sarandon [1991], Peltonen and Virtanen [1994], Kościelniak and Rothkaehl [2000], Podolska *et al.* [2004], Ellmann *et al.* [2005], Stankowski and Rutkowska [2006], Sypuła and Dadrzyńska [2008]. No significant reaction of this trait to intensification of plant protection was found. Piekarczyk [2010], however, proves that intensification of plant protection against agrophages improves it.

Results of a lot of studies indicate effects of the activity of nitrogen fertilization [Klupczyński *et al.* 2001, Ceglińska *et al.* 2002, Cacak-Pietrzak *et al.* 2005, Podolska 2008], level of plant protection against agrophages [Podolska *et al.* 2004, Mularczyk *et al.* 2010, Narkiewicz-Jodko *et al.* 2010], delayed harvest [Witkowska *et al.* 2000, Ellmann *et al.* 2005] and grain storage [Janowicz 2007] on particular quality traits of the grain.

In the research, an attempt was made to prove the effects of complex activity of plant protection intensity, nitrogen fertilization, harvest time and storage time, on the quality traits of grain and flour**.** However, no correlative effect on these parameters was confirmed.

RESULTS

1. Intensification of the protection level of wheat cv. Bogatka affected the increase of the weight of one thousand grains and the content of washed gluten. However, it did not have an effect on hectoliter weight, grain vitreousness and gluten extensibility.
2. Together with an increase of nitrogen rate, there occurred an increase of hectoliter weight and grain vitreousness, and also gluten content in it definitely increased. Weight of one thousand grains and gluten extensibility did not change.
3. Harvest delay caused increase of the weight of one thousand grains, deterioration of hectoliter weight and of its vitreousness. Gluten efficiency decreased, though its weakening did not change.
4. Best quality grain was obtained from winter wheat which was intensively protected, fertilized with 140 and 180 kg $N \cdot ha^{-1}$, and harvested at the optimum time. Grain storage in proper conditions for half a year did not significantly change its parameters.
5. No correlative effect of intensity of plant protection against agrophages, diversified nitrogen rates, harvest time or time of grain storage on the studied quality parameters was found.

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WPŁYW INTENSYWNOŚCI AGROTECHNIKI I PRZECHOWYWANIA ZIARNA NA WARTOŚĆ TECHNOLOGICZNĄ PSZENICY OZIMEJ CZ. I. CECHY JAKOŚCIOWE ZIARNA I MĄKI

Streszczenie. W pracy przedstawiono ocenę jakościową ziarna i mąki z pszenicy ozimej odmiany Bogatka, uprawianej w latach 2007-2009 na glebie brunatnej właściwej, kompleksu pszennego dobrego. Czynnikami doświadczalnymi były: ochrona roślin (ekstensywna, intensywna), nawożenie azotem (60, 100, 140, 180 kg $N \cdot ha^{-1}$), termin zbioru (optymalny i opóźniony o 2 tygodnie) oraz czas przechowywania ziarna. Ocenę jakościową ziarna wykonano bezpośrednio po zbiorze oraz po jego półrocznym przechowywaniu. Oznaczono: masę tysiąca ziaren, gęstość w stanie zsypnym, szklistość i mączystość ziarna oraz ilość i jakość glutenu. Intensyfikacja poziomu ochrony roślin nie wpływała istotnie na gęstość ziarna w stanie zsypnym, szklistość ziarniaków i rozpływalność glutenu, zwiększała natomiast jego ilość i masę tysiąca ziaren. Wzrost nawożenia azotowego wpływał na zwiększenie gęstości ziarna w stanie zsypnym i jego szklistości, a także ilości wymytego glutenu; rozpływalność glutenu pozostała bez zmian. Opóźnienie zbioru skutkowało pogorszeniem gęstości ziarna i jego szklistości oraz zmniejszeniem wydajności glutenu, nie zmieniała się natomiast jego rozpływalność.

Słowa kluczowe: gęstość ziarna, gluten, nawożenie azotem, poziom ochrony roślin, rozpływalność glutenu, szklistość ziarna, termin zbioru

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