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Influence of Nitrogen Fertilization on the Yields and Grain Quality of Winter Wheat under Different Environmental Conditions

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Abstract**—**In 2013/2014 and 2014/2015, a field experiment was conducted in two locations: Osiny and Wielichowo (Poland). The two-factor experiment was based on the method of randomized subblocks, in three replications. The first factor (A) was dose of nitrogen fertilization (two levels). The second factor (B) was nine winter wheat cultivars. It was found that winter wheat cultivars exhibited different reactions to higher nitrogen fertilization depending on the years and localities. Only KWS Dacanto cultivar under all growing conditions showed a significant increase in grain yield after the application of a higher level of nitrogen fertilization. The increase in nitrogen fertilization influenced the increase in gluten proteins content in wheat grain, but these changes were statistically significant only in the first year of the study. The quality of gluten does not depend on nitrogen fertilization. The quality of wheat grain depends on cultivars.

Keywords—Fertilization, grain quality, winter wheat, yield.

I. Introduction

WHEAT is one of the most important crops grown in the world in terms of geographical distribution, area cultivated and total production. Most of the wheat grain produced (75-78%) is processed for consumption [1]. Due to its chemical composition and unique technological properties, wheat grain is an important raw material for the production of flour for baking purposes. Wheat cultivation, focused on the production of consumer grain, should be carried out in such a way as to obtain a high grain yield with appropriate quality parameters [2].

The yield and quality of wheat grain is influenced by genetic, environmental factors and interactions between them [3]-[5]. According to literature data [4]-[7], wheat yield can be increased through the use of intensive agrotechnology, first of all through increased nitrogen fertilisation. However, individual wheat cultivars show different responses to the applied doses of fertilizers and not always the obtained increase in yield is profitable in relation with the financial inputs incurred on more intensive agrotechnics [8], [9]. Nitrogen fertilization applied in cultivation also affects the quality of the obtained grain, which primarily concerns the content and composition of protein substances. Along with an increase in the nitrogen dose, the protein content, including gluten proteins, increases to a certain level [8], [10].

In the research hypothesis, it was assumed that wheat cultivars differ in reaction to nitrogen fertilization, and grain yield and quality are determined by habitat conditions. The aim of the study was to determine the effect of nitrogen fertilization on the yield and selected qualitative characteristics of grain of nine winter wheat cultivars cultivated in two localities with different soil and climatic conditions.

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II. Material and Methods

The research was carried out in 2013/2014 and 2014/2015 in two experimental plants Osiny and Wielichowo, which belong to the Institute of Soil Science and Plant Cultivation - State Research Institute in Puławy, Poland. The soil conditions are presented in Table I. The two-factor experiment was established using the method of random blocks in three replications. The first factor (A) was the dose of nitrogen fertilization (120 and 200 kg $N \cdot ha^{-1}$). Mineral nitrogen was applied at three dates (40% of the dose at the start of the growing season, 30% in the full tillering phase, and 30% in the earing phase). The second factor (B) was nine winter wheat cultivars of diversified quality class (Table II). The forecrop was winter rape. The area of an individual plot was 15 m^2. Sowing was performed in accordance with the requirements for this species. After harvest, the grain yield per 1 ha and the selected features of the technological value of grain were determined.

In order to determine the technological value of grains after harvest, representative samples of grain were taken using the principles of the PN-72/A-74001 standard. In grain samples, the amount of wet gluten, gluten index (IG) a Glutomatic 2200 (AACC Method 38-12), falling number a Falling Number Test Apparatus type 1400 (AACC Method 56-81B) were determined.

The results were statistically analyzed using a two-way ANOVA, using the Statgraphics Centurion XVI computer program. Significance of differences between means were evaluated using the Tukey test at the level of significance p=0.05.

III. Results

The course of thermal conditions in the localities where the field tests were conducted was similar. The autumn and winter seasons in both growing seasons were warmer than the conditions prevailing during the long-term period (the norm). On the other hand, from May to June thermal conditions were colder than -0.8 to -1.9 °C. Generally, thermal conditions in the first year of the study were warmer than in the second year, especially in July (20.7 and 21.1 °C). In the second year of the study, the warmest month was August (21.8-22.3 °C).

In both localities, large differences in precipitation were found. In the 2013/14 growing season in Osiny (Fig. 1 (a)), the total precipitation was 785 mm, being 36% higher than the long-term average. In this period, particularly high precipitation occurred in April, May, June and August, which was respectively: 183%, 350%, 170% and 151% of the precipitation norm.

TABLE I
CHARACTERISTICS OF THE SOIL AT THE EXPERIMENTAL SITES

Location	Latitude longitude	Season	Soil type	Complex of agricultural usefulness	Soil pH in KCL
Osiny	(51.47°N, 22.05 °E)	2013/2014 2014/2015	haplic podzol	good wheat	6.7
Wielichowo	(52.12 °N, 16.36 °E)	2013/2014 2014/2015	Haplic luvisol	rye good	5.8

TABLE II
ORIGIN OF THE CULTIVARS THAT WERE USED IN THE EXPERIMENT AND ABBREVIATION OF THE NAMES OF THE CULTIVARS

Cultivar	Quality class	Country of origin	Breeder, distributor
Astoria	E*	PL	Poznańska Hodowla Roślin Sp. zo.o.
Bamberka	A	PL	Hodowla Roślin Strzelce sp. z o.o.
Fidelius	B	PL	DANKO Hodowla Roślin sp. z o.o.
Forkida	C	PL	DANKO Hodowla Roślin sp. z o.o.
Kampana	B	PL	DANKO Hodowla Roślin sp. z o.o.
Kepler	A	FR	Limagrain Central Europe Societe Europeenne Spółka Europejska Oddział w Polsce
KWS Dacanto	B	DE	KWS Lochow Polska sp.zo.o.
Meister	B	FR	RAGT Semences Polska sp. z o.o.
Oxal	A	FR	RAGT Semences Polska sp. z o.o.

E=elite, A=bread quality, B=bread, C=fodder.

In Wielichowo (Fig. 1 (b)) in the 2013/2014 growing season, the total precipitation was 396 mm, being 28% lower than the norm. The highest precipitation was recorded in March (46 mm), May (52 mm) and July (65 mm), which was respectively: 139%, 102% and 86% of the precipitation standard. On the other hand, in April and June the precipitation was low, i.e. 54% and 42% of the norm.

In the 2014/15 growing season, the rainfall in both towns was lower than normal - in Osiny by 16%, and in Wielichowo by 26%. In Osiny, high precipitation occurred in March (55 mm) and May (114 mm), respectively: 190% and 211% of the precipitation norm. At the final stage of growing season in June, July and August, precipitation was below the standard and constituted, respectively: 46%, 62% and 7% of the norm.

A. Yields of Winter Wheat Cultivars

In the years of the study, a higher level of wheat yields was obtained for the crops in Osiny on the soil of a good wheat complex. In the harvest year 2014 and 2015 in Osiny, the grain yields were higher to the yield obtained in Wielichowo, respectively 14 and 18% (Tables III and IV). In each year of the study, an average higher grain yield was obtained from plots fertilized with a dose of 200 kg N·ha^{-1}, whereas in the harvest year 2014 in Osiny and in 2015 in Wielichowo these differences were not statistically significant. A different response of winter wheat cultivars to a higher level of nitrogen fertilization was recorded. In 2014 in Osiny, a significant increase in grain yield after the application of a higher nitrogen dose was obtained for cultivars: Fidelius (20%), Kampana (18%), KWS Dacanto (11%) and Meister (9%). In 2015 a very strong reaction to a higher nitrogen dose was observed in Kampana cultivar, whose yield increased by as much as 32%. Also, a significant increase in grain yield was observed in cultivars: Bamberka (19%), Forkida (13%), Kepler (14%) and KWS Dacanto (12%). In Wielichowo, in the harvest year 2014, all winter wheat cultivars productively used a higher nitrogen dose, but the highest increase in grain yield under the influence of a higher nitrogen dose was achieved by Fidelius cultivar (35%), a slightly lower Meister cultivar (32%). In the following year of the study in Wielichowo, a positive reaction to a higher level of nitrogen fertilization of cultivars was found: Oxal (22%), Meiser (12%) Kepler (11%) and KWS Dacanto (9%).

B. Wet Gluten Yield

The yield of wet gluten washed out of wheat grain from the 2014 harvest depended significantly on nitrogen fertilization, genotype, and interactions among these factors (Tables V and VI). Significant influence of the factors mentioned above was demonstrated for wheat grain grown in Osiny and Wielichowo. An increase in nitrogen fertilization from 120 to 200 kg·ha^{-1} resulted in an increase in wet gluten yield, with a higher increase in wet gluten yield for wheat grain grown in Wielichowo than for Osiny (mean increase by 2.9% and 2.3%, respectively). Wheat grain from this location in both years of field research, contained slightly more gluten proteins than the grains from Osiny. The occurrence of a significant interaction between fertilization and genotype indicates an uneven reaction of cultivars to nitrogen fertilization applied.

A statistically significant increase in gluten proteins, resulting from the application of increased nitrogen doses, was found for wheat grown in Osiny for cultivars: Bamberka, KWS Dacanto, Fidelius, Forkida, Kampana, Meister and Oxal, whereas in Wielichowo for cultivars: Forkida, Kampana and Meister. In 2014, regardless of the place of cultivation, the highest efficiency of wet gluten was found in the grains of Kepler and Oxal wheat cultivars. In the second year of the study (grain from the 2015 harvest), regardless of the place of cultivation (Osiny, Wielichowo), there was no significant effect of nitrogen rates on wet gluten yield, whereas it depended significantly only on the genotype. The highest gluten yield was observed for wheat grains of Oxal and Forkida cultivars (Osiny), and Oxal, Fidelius and KWS Dacanto cultivars (Wielichowo).

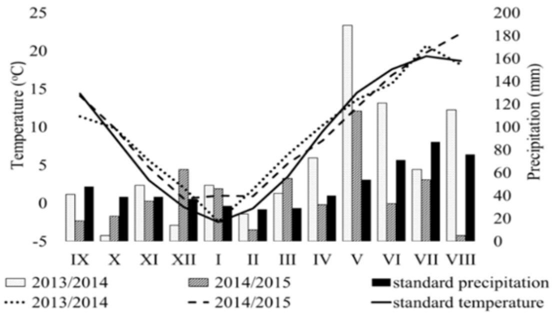
C. Quality of Wet Gluten

In both years of the study, regardless of the place of cultivation (Osiny, Wielichowo), the level of nitrogen fertilization did not affect the quality of gluten (Tables VII and VIII). The mean IG values for wheat grain grown in Osiny ranged from 65-69, and for wheat cultivated in Wielichowo ranged from 65 to 75 on average. The genotype had a significant influence on gluten quality. In 2014, wheat grains of the Forkida and Oxal (Osiny) and Forkida and Astoria (Wielichowo) cultivars were characterized by the best quality gluten, while the grains of the Fidelius cultivar (in both cultivation locations), the worst. In 2015, the best quality gluten was washed from wheat grain of Astoria and Forkida (Osiny) and Astoria and Kampana (Wielichowo), while the worst from the grains of Kepler (Osiny) and Oxal (Wielichowo) cultivars.

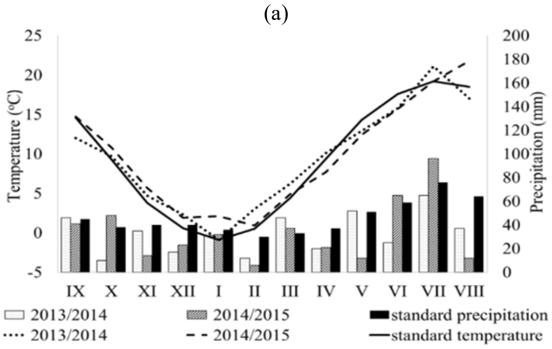
D. Activity of Amylolytic Enzymes

The activity of amylolytic enzymes in wheat grains from the 2014 harvest in Osiny depended significantly on the level of nitrogen fertilization, genotype and interactions of these factors, while in the grains from the Wielichowo, on the genotype and interaction between fertilization and genotype (Tables IX and X). The response of the studied wheat cultivars to the increase in nitrogen fertilization level was uneven. In the case of wheat cultivated in Osiny, a statistically significant increase in the falling number, indicating amylolytic activity decrease, was found for the grains of Astoria and Kepler cultivars, whereas a decrease in the value of this index occurred in the case of Forkida cultivar. In the case of wheat cultivated in Wielichowo, a statistically significant decrease in the falling number was recorded for the grains of the Kampana cultivar. Differentiation of nitrogen fertilization level did not cause statistically significant changes in amylolytic activity of grains of other investigated wheat cultivars. In 2015, the amylolytic activity of wheat grain from both places of cultivation was significantly affected only by the genotype.

The majority of grain samples tested, irrespective of the place and year of cultivation, showed low amylolytic activity. In 2014 the average amylolytic activity was observed in wheat grains of Fidelius (Osiny – both nitrogen fertilization levels, Wielichowo – 200 kg N·ha^{-1}), Bamberka (Osiny – both nitrogen fertilization levels), Astoria and Kampana (Osiny, 120 kg N·ha^{-1}), Forkida (Osiny, 200 kg N·ha^{-1}), Kampana (Wielichowo, 120 kg N·ha^{-1}) and Fidelius cultivars (Wielichowo, 200 kg N·ha^{-1}). In 2015, the average amylolytic activity was recorded only for the grain of the Kampana cultivar grown in Osiny (both levels of fertilization).



(a)



(b)

Fig. 1 Meteorological conditions in two locations: a) OSINY, b) WIELICHOWO

TABLE III
GRAIN YIELD (T·HA^{-1}) IN WINTER WHEAT IN OSINY

Cultivar	Year					
	2014			2015		
	Nitrogen fertilization (kg·ha^{-1})					
	120	200	Mean	120	200	Mean
Astoria	9.28	9.86	9.57	9.05	9.37	9.21
Bamberka	8.35	9.07	87.1	8.62	10.28	9.45
Fidelius	8.57	10.27	9.42	10.14	10.45	10.29
Forkida	9.45	10.50	9.97	9.13	10.38	9.75
Kampana	7.88	9.35	8.11	8.35	11.01	9.68
Kepler	9.44	9.66	9.55	9.19	10.48	9.83
KWS Dacanto	8.49	9.48	8.98	9.41	10.58	9.99
Meister	9.38	10.23	9.80	10.20	11.08	10.64
Oxal	9.50	10.08	9.79	9.10	9.42	9.26
Mean	8.92	9.83		9.29	10.33	

LSD $_{0.05}$ for A = n.s.; B =0.685; B/A = 0.969; A = 0.184; B = 0.426; B/A = 0.602

n.s. = not significant differences for p=0.05.

TABLE IV
GRAIN YIELD ($t \cdot ha^{-1}$) IN WINTER WHEAT IN WIELICHOWO

Cultivar (B)	Year					
	2014			2015		
	Nitrogen fertilization ($kg \cdot ha^{-1}$) (A)					
	120	200	Mean	120	200	Mean
Astoria	7.42	8.28	7.85	7.35	7.50	7.42
Bamberka	6.80	8.06	7.43	7.40	7.85	7.62
Fidelius	4.10	5.56	4.83	8.45	8.10	8.27
Forkida	6.04	7.38	6.71	7.45	8.10	7.77
Kampana	8.15	8.92	8.53	8.10	8.25	8.17
Kepler	8.13	9.72	8.92	7.55	9.25	7.90
KWS Dacanto	8.15	8.75	8.45	7.70	8.40	8.05
Meister	6.26	8.27	7.26	8.30	9.25	8.77
Oxal	8.24	9.66	8.95	7.60	8.55	8.07
Mean	7.03	8.29		7.77	8.36	
LSD $_{0.05}$ for A= 0.875; B = 0.216; B/A = 0.306; A= n.s.; B = 0.441; B/A = 0.623						

n.s. = not significant differences for p=0.05.

TABLE V
GLUTEN CONTENT (%) IN WINTER WHEAT IN OSINY

Cultivar	Year					
	2014			2015		
	Nitrogen fertilization ($kg \cdot ha^{-1}$)					
	120	200	Mean	120	200	Mean
Astoria	28.1	28.9	28.5	23.9	24.2	24.0
Bamberka	23.4	26,9	24.7	25.7	25.9	25.8
Fidelius	23.1	27.4	25.3	27.2	27.7	27.4
Forkida	27.3	29.0	28.2	27.6	28.1	27.8
Kampana	25.6	28.9	27.2	22.8	23.3	23.0
Kepler	31.6	30.6	31.1	26.7	26.7	31.0
KWS Dacanto	26.9	29,1	28.0	26.3	24.4	26.3
Meister	22.8	25.4	24.1	24.0	24.5	24.2
Oxal	28.6	32,2	30.4	30.7	30.8	30.7
Mean	26.4	28.7		26.1	26.2	
LSD $_{0.05}$ for A= 0.63; B = 0.74; B/A = 1.05; A= n.s.; B = 5.03; B/A = n.s						

n.s. = not significant differences for p=0.05.

TABLE VI
GLUTEN CONTENT (%) OF WINTER WHEAT IN WIELICHOWO

Cultivar	Year					
	2014			2015		
	Nitrogen fertilization ($kg \cdot ha^{-1}$)					
	120	200	Mean	120	200	Mean
Astoria	32.2	32.1	32.1	28.5	29.3	29.1
Bamberka	26.7	29.7	28.2	31.8	31.1	32.0
Fidelius	29.4	27.9	28.6	32.6	32.8	32.7
Forkida	24.2	29.8	26.6	30.5	30.7	30.6
Kampana	23.6	30.3	26.9	28.3	28.2	28.3
Kepler	36.3	39.4	37.9	30.0	30.1	30.1
KWS Dacanto	26.6	29.2	27.9	32.2	32.5	32.3
Meister	22.1	28.3	25.2	30.8	31.0	30.9
Oxal	35.2	36.7	36.0	33.1	33.4	33.2
Mean	28.5	31.4		30.9	31.1	
LSD $_{0,05}$ for A= 2.41; B = 4.08; B/A = 5.03; A = n.s.; B = n.s.; B/A = n.s						

n.s. = not significant differences for p=0.05.

IV. DISCUSSION

The presented results indicate that winter wheat yields were differentiated by habitat conditions (Tables III and IV). The highest yields were obtained by wheat grown in Osiny on the soil classified as good wheat complex. Literature data indicate a significant dependence of wheat yields on soil conditions [4], [11]. Podolska and Filipiak [11] indicate that wheat cultivated on the soil of good wheat complex yielded higher by 43% compared to grain yield obtained on good rye complex. In the other studies [12], a large diversity of winter wheat yields depending on the soil type of agricultural suitability. These authors stated that winter wheat gave the highest grain yields when it was cultivated on soils of a very good wheat complex, by 5.5% lower on soils of a good wheat complex, by 9.7% lower on soils of a very good rye complex, while the lowest (by 19.7%) on soils of a good rye complex. Rozbicki et al. [4] also stated that there is an interaction between the growing region and winter wheat yields.

TABLE VII
GLUTEN INDEX (-) OF WINTER WHEAT GRAIN IN OSINY

Cultivar	Year					
	2014			2015		
	Nitrogen fertilization ($kg \cdot ha^{-1}$)					
	120	200	Mean	120	200	Mean
Astoria	77	79	78	92	90	91
Bamberka	69	76	73	76	71	74
Fidelius	21	50	36	46	47	47
Forkida	83	78	81	90	86	88
Kampana	53	35	44	55	68	62
Kepler	47	32	39	38	39	39
KWS Dacanto	65	69	67	48	56	52
Meister	77	81	79	80	82	81
Oxal	95	96	96	81	82	82
Mean	65	66		67	69	
LSD $_{0.05}$ for A= n.s.; B = 23.3; B/A = n.s.; A= n.s.; B = 26.9; B/A = n.s						

n.s. = not significant differences for p=0.05.

TABLE VIII
GLUTEN INDEX (-) OF WINTER WHEAT GRAIN IN WIELICHOWO

Cultivar	Year					
	2014			2015		
	Nitrogen fertilization ($kg \cdot ha^{-1}$)					
	120	200	Mean	120	200	Mean
Astoria	83	86	85	88	86	87
Bamberka	86	77	82	79	61	70
Fidelius	30	32	31	52	50	51
Forkida	97	89	93	75	75	75
Kampana	73	61	67	85	85	85
Kepler	54	57	56	58	70	64
KWS Dacanto	72	72	72	50	74	62
Meister	96	48	72	64	83	74
Oxal	87	59	73	46	30	38
Mean	75	65		66	68	
LSD $_{0.05}$ for A = n.s.; B = 21.8; B/A = 30.9; A = n.s.; B = 20.2; B/A = n.s						

n.s. = not significant differences for p=0.05.

Our studies showed different levels of yields of the cultivars in the study years and localities, depending on the level of nitrogen fertilization. This indicates the existence of interactions between soil-climatic conditions and wheat cultivars' characteristics. The studies confirm the impact of nitrogen use by plants on temperature, precipitation and sunshine, and thus on yield levels [13]. Among the cultivars studied, regardless of location and years, only KWS Dacanto responded positively to a higher rate of nitrogen fertilization. Other cultivars exhibited different responses to higher nitrogen doses in years and localities. Earlier studies [14]-[16] had confirmed that the use of nitrogen depends on the genetic factor.

TABLE IX
FALLING NUMBER (S) OF WINTER WHEAT GRAIN IN OSINY

Cultivar	Year					
	2014			2015		
	Nitrogen fertilization (kg·ha^{-1})					
	120	200	Mean	120	200	Mean
Astoria	270	365	317	428	427	427
Bamberka	279	281	280	355	357	356
Fidelius	260	250	255	331	337	334
Forkida	316	279	297	415	424	420
Kampana	291	305	298	256	250	253
Kepler	323	358	340	377	385	386
KWS Dacanto	339	342	340	384	391	388
Meister	347	347	347	431	446	439
Oxal	345	335	340	389	382	386
Mean	308	318		374	377	

LSD $_{0.05}$ for A = 5.6; B = 18.8; B/A = 26.7; A = n.s.; B = 90.3; B/A = n.s

n.s. = not significant differences for p=0.05.

TABLE X
FALLING NUMBER (S) OF WINTER WHEAT GRAIN IN WIELICHOWO

Cultivar	Year					
	2014			2015		
	Nitrogen fertilization (kg·ha^{-1})					
	120	200	Mean	120	200	Mean
Astoria	419	406	413	391	386	389
Bamberka	389	359	374	471	467	469
Fidelius	304	272	288	362	358	360
Forkida	417	386	401	396	394	395
Kampana	294	332	313	382	383	383
Kepler	462	455	458	465	460	463
KWS Dacanto	398	392	395	400	392	396
Meister	385	372	379	320	324	322
Oxal	422	414	418	318	321	320
Mean	388	377		389	387	

LSD $_{0.05}$ for A = n.s.; B = 24.0; B/A = 33.9; A = n.s.; B = 88,4.; B/A = n.s

n.s. = not significant differences for p=0.05.

The technological value of wheat grain depends on the chemical composition and physicochemical properties of individual components and interactions between them. Among the chemical components, the most important in shaping technological properties of wheat is attributed to reserve proteins - gliadin and glutenin. After mixing these proteins with water, they form a gluten complex characteristic for the structure of wheat dough. They perform the structure-forming function in bread, which results from their ability to form a branched structure, which during dough mixing, surrounds swollen starch grains and determines the retention of gases produced during dough fermentation [2], [17].

The content and quality of protein substances in wheat grain are genetically determined, but these components are also influenced by habitat conditions (soil agricultural suitability complex, climatic conditions, agrotechnical treatments) [2], [4], [10], [18]. Grains of the tested wheat cultivars exhibited a diversified content of gluten proteins. The grains of Oxal cultivar were characterized by the highest, while the grains of Meister cultivar by the lowest content of this component. The cultivars KWS Dacanto Fidelius, Forkida and Kepler also contained high concentrations of gluten proteins. In the first year of the study, an increase in nitrogen fertilization resulted in a significant increase in wet gluten yield, while a higher increase in the content of this component was found in the case of wheat grain grown in Wielichowo, where soil conditions were less favorable than in Osiny. In the second year of the study, increased nitrogen fertilization also, in general, resulted in an increase of wet gluten yield, but these changes were not statistically significant. Positive effects of nitrogen fertilization on gluten protein content in wheat grain were also indicated by earlier studies [2], [4], [8], [10], [13], [18]-[22]. Literature data [2], [23], [24] show that a higher accumulation of protein substances occurs in dry and sunny weather conditions in the period from earing to waxy maturity of the grain. This was confirmed by the results of this study. The grain of wheat cultivated in Wielichowo, where the amount of precipitation was lower than in Osiny, was characterized by a higher gluten protein content.

In addition to the content of gluten proteins, their quality is also important. Flour with a gluten index in the range of 60-90 units is the most suitable for baking bread. At more than 90 GI values, gluten is strong and short, whereas if the GI is below 40, gluten is weak [2]. Gluten washed out of the grain of most of the wheat cultivars was of good baking quality. The weakest gluten was found in the grain the Kepler wheat cultivar. In this study, the level of nitrogen fertilization had no significant influence on the quality of gluten. It depended exclusively on varietal traits, which had been confirmed by the results of earlier studies [2], [13], [18].

The falling number determining the α-amylase activity is an important indicator of grain health. It is related to the resistance of the cultivar to overgrowth [2]. In the present study, the values of this qualitative differentiator depended significantly on the genotype, which is confirmed by literature data [2], [4], [10], [18]. Earlier studies [2] had shown that the activity of amylolytic enzymes is strongly influenced by weather conditions prevailing during grain ripening and harvesting. If there is little precipitation during this period, the grain has a low amylolytic activity, while the increased amount of precipitation results in an increase in amylolitic activity of the grain, which may even lead to its overgrowth. This has been partially confirmed by the results of this work. The majority of the tested grain samples were characterized by low amylolytic activity (falling number values > 300s), while the remaining samples were characterized by medium amylolytic activity, which generally resulted from lower precipitation compared to the long-term average. The highest amylolytic activity was observed in wheat grain cultivated in Osiny in the 2013/2014 season, i.e. in conditions where the amount of precipitation was the highest.

A lower amylolytic activity was observed in wheat grain from the 2015 harvest, in which the amount of precipitation was lower than in 2014. Differentiated nitrogen fertilization applied in cultivation significantly influenced the activity of amylolytic enzymes, only in the case of wheat grain harvested in 2014 in Osiny. Statistically significant changes in the number of descent caused by an increase in the nitrogen dose were found for three out of the nine wheat cultivars studied. In the case of two cultivars (Astoria, Kepler), along with the increase in nitrogen dose, the amylolytic activity of grain decreased, while in the case of the Forkida cultivar the increase. The study by [10] showed that with the increase in the nitrogen rate, the activity of amylolytic enzymes in wheat grain decreased. In the case of other samples of wheat grain (harvest 2014 - Wielichowo, harvest 2015 - Osiny, Wielichowo) the increase in nitrogen fertilization did not affect the activity of amylolytic enzymes, which had been confirmed in earlier studies [2], [4], [13], [18].

V. Conclusion

A different response of wheat cultivars to a higher level of nitrogen fertilization was found, depending on the years and localities. Only KWS Dacanto cultivar in all cultivation conditions showed a significant increase in grain yield (10%) after increasing fertilization to 200 kg N·ha^{-1}. The increase in nitrogen fertilization level influenced the increase in gluten protein content in wheat grain, but only in the first year of the study these changes were statistically significant. The level of nitrogen fertilization did not affect the quality of gluten and the activity of amylolytic enzymes. The genetic factor had a greater influence on the quality of wheat grain.

References

[1] A. Psaroudaki, "An extensive survey of the impact of tropospheric ozone on the biochemical properties of edible plants", WSEAS Tran Environment and Development, 2007, 3, pp. 99-110.

[2] G. Cacak-Pietrzak, "Studia nad wpływem ekologicznego i konwencjonalnego systemu produkcji roślinnej na wartość technologiczną wybranych odmian pszenicy ozimej (The studies on the impact of ecological and conventional plant production system on the technological value of selected winter wheat varieties" Wyd. SGGW, Warszawa, 2011, pp. 11-26.

[3] L. Hlisnikovsky, E. Kunzova, M. Hejcman, V. Dvoracek, "Effect of fertilizer application, soil type and year on yield and technological parameters of winter wheat (*Triticum aestivum*) in the Czech Republic", Arch. Agron. Soil Sci., 2015, 61, pp. 33-53.

[4] J. Rozbicki, A. Neglińska, D. Gozdowski, M. Jakubczak, G. Cacak-Pietrzak, W. Mądry, J. Golba, M. Piechociński, G. Sobczyński, M. Studnicki, and T. Drzazga, "Influence of the cultivar, environment and management on the grain yield and bread-making quality in winter wheat", J. Cer. Sci., 2015, 61, pp. 126-132.

[5] Golba J., M. Studnicki, Gozdowski D., W. Mądry, and J. Rozbicki, "Influence of genotype, crop management, and environment of winter wheat grain yield determination based on components of yield", Crop Sci., 2018, vol. 58, pp. 660-669.

[6] F. Cormier, S. Faure, P. Dubreuil, E. Heumez, K. Beauchene, S. Lafarge, S. Praud, and J. Le Gouis, "A multi-environmental study of recent breeding progress on nitrogen use efficiency in wheat (*Triticum aestivum* L.)", Theor. Appl. Genet., 2013, 126, pp. 3035-3048.

[7] J. Golba, J. Rozbicki, D. Gozdowski, D. Sas, W. Mądry, M. Piechociński, L. Kurzyńska, M. studnicki, and A. Derejko, "Adjusting yield componenys under different levels of N application in winter wheat", Int. J. Plant Prod., 2013, 7(1), pp. 139-150.

[8] B.L. Duggan, R.A. Richards, A.F. van Herwaarden, and N.A. Fettel, "Agronomic evaluation of triller inhibition gene (tin) in wheat. I Effect on yield, yield components, and grain protein", Aust. J. Agric. Res., 2005, 56, pp. 169-178.

[9] M.F. Dreccer, S.C. Chapman, A.R. Rattey, J. Neal, J.T. Christopher, and M. Reynolds, "Developmental and growth controls of tillering and water-soluble carbohydrate accumulation in contrasting wheat (*Triticum aestivum* L.) genotypes: can we dissect them?", J. Exp. Bot., 2013, 64, pp. 143-160.

[10] A. Szafrańska, G. Cacak-Pietrzak, A. Sułek, "Influence of nitrogen fertilization and retardants on baking value of the winter wheat", EJPAU, 2008, 11(4), p. 28

[11] G. Podolska, K. Filipiak, "Effect of environment conditions on grain yield and grain quality of winter wheat", Część II, Zesz. Probl. Post. Nauk Rol., 2009, 542, pp. 397-404.

[12] K. Noworolnik, G. Podolska, "Response of winter wheat cultivars to various soil conditions", 2017, Fragm. Agron., 34(4), pp. 125-133.

[13] E. Harasim, M. Wesołowski, " Wpływ retardantu Moddus 250 EC i nawożenia azotem na plonownie i jakość ziarna pszenicy ozimej (The impact of Modys 250 EC retardant and nitrogen fertilization on yields and grain quality of winter wheat", Fragm. Agron., 2013, 30(3), pp. 70-77.

[14] G. Podolska, M. Wyzińska, „The response of winter wheat cultivars to nitrogen fertilization in pot experiments", Pol. J. Agron., 2011, 5, pp. 43-48.

[15] G. Podolska, A. Sułek, "Effect cultivation intensity on grain yield and yield components of winter wheat cultivars", Pol. J. Agron,, 2012, 11, pp. 41-46.

[16] Rozbicki, G. Sobczyński, "Influence of cultivar and nitrogen nutritional status on winter wheat yield-forming traits pot experiment. Part II. Impact of nitrogen nutrition status on yield components", Fragm. Agron., 2016, 33(4), pp. 110-122.

[17] A.H. Bloksma, "Rheology of the breadmaking process", Cer. Foods World, 1990, 35(2), pp. 228-236.

[18] G. Podolska, G. Cacak-Pietrzak, A. Neglińska, M. Mikos, J. Chrzanowski, „Wpływ sposobu aplikacji azotu na wartość technologiczną odmian pszenicy ozimej (The influence of the nitrogen application method on the technological value of winter wheat varieties", Pam. Puławski, 2010, 152, pp. 215-226.

[19] I.M. Petroczi, Z. Kovacs, L. Bona, „Influences of agronomics factors on the yield and quality of winter wheat by nitrogen inputs", Sci. Pap. – Ser. A – Agron., 2008, 61, pp. 310-315.

[20] E. Harasim, M. Wesołowska-Trojanowska, „Wpływ nawożenia azotem na plonowanie i jakość technologiczną ziarna pszenicy ozimej (The effect of nitrogen fertilization on the yield and technological quality of winter wheat grain", Pam. Puławski, 2010, 152, pp. 77-84.

[21] V. Zecevic, D. Knezevic, J. Boskovic, D. Micanovic, and G. Dozet, "Effect of nitrogen fertilization on winter wheat quality", Cer. Res. Commun., 2010, vol. 38, pp. 243-249.

[22] R.M. Madjar, G. Vasile-Scaeteanu, and A. Andreea, "Improve of grain yield and quality of winter wheat by nitrogen inputs", Sci. Pap. – Ser. A – Agron., 2018, vol. 61, pp. 310-315.

[23] C. Daniel, E. Triboi, "Effect of temperature and nitrogen nutrition on the grain composition of winter wheat: effect on gliadin content and composition", J. Cer. Sci., 2000, 32, pp. 45-56.

[24] F.M. Dupont, W.J. Hurkman, W.H. Vensel, C. Tanaka, K.M. Kothari, O.K. Chung, and S.B. Altenbach, "Protein accumulation and composition in wheat grains: effect of mineral nutrients and higt temperature", Europ. J. Agron., 2006, 25, pp. 96-107.

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