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EFFECT OF NITROGEN FERTILIZATION ON YIELD AND GRAIN TECHNOLOGICAL QUALITY OF SOME WINTER WHEAT CULTIVARS GROWN ON LIGHT SOIL

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Abstract. In the field experiment, conducted in 2007-2010 in Mochełek (53°13' N; 17°51' E) near Bydgoszcz on good rye complex, the effect of nitrogen fertilization (40, 80, 120, 160 kg N·ha^{-1}) on the yield and grain technological quality of winter wheat cultivars Bogatka, Nutka, Kris, Tonacja was evaluated. The study found that in agricultural techniques of winter wheat on light soil, cultivar and nitrogen fertilization are elements having an independent effect. Under these soil conditions, in this region and in the years of relatively low rainfall totals during the growing season, nitrogen fertilization above 80 kg N·ha^{-1} did not significantly increase the grain yield, but positively affected its technological value. Among the compared winter wheat cultivars, Kris cultivar yielded the best. Grains of this cultivar, however, had the lowest grain technological quality.

Key words: falling number, flowness of gluten, gluten content, Zeleny sedimentation index

INTRODUCTION

Under unfavourable soil conditions, production effects of winter wheat cultivation to a large degree depend on the type of forecrop and weather conditions [Kuś and Siuta 1995, Rudnicki 2005, Piekarczyk 2007, 2010a]. Favourable distribution of rainfall in the growing season increases effectiveness of nitrogen fertilization, significantly influencing the quantity and quality of the wheat grain yield [Podolska and Sułek 2002, Fotyma 2003, Blecharczyk et al. 2006]. An important element of the grain production for consumption purposes is also the selection of cultivars of genetically fixed high technological quality of the grain [Lista opisowa... 2009]. However, under production conditions, these traits manifest themselves to a different degree which depends on the habitat factors and agricultural techniques [Podolska and Sułek 2002, Mazurkiewicz and Bojarczyk 2004]. The effect of nitrogen fertilization on the yield of winter wheat as a species may be regarded as well-identified [Knapowski and Ralcewicz 2004,

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Mazurkiewicz and Bojarczyk 2004, Stankowski et al. 2004, Podolska et al. 2007]. The determination of its influence on the currently grown cultivars seems to be necessary, especially under less favorable soil conditions.

In view of partly complementary effect of genetic, habitat and agricultural technique factors on plants, it is assumed that on light soil, under unfavorable conditions for winter wheat cultivation, cultivar selection and nitrogen fertilization have a particular significance for its yield and grain quality. The reaction of cultivars of genetically diversified yield potential and of diversified grain technological quality to the level of fertilization may be various.

The aim of the research was the determination of the independent and interactive effect of nitrogen fertilization on the yield and grain quality of several winter wheat cultivars, diversified in agricultural and utility characteristics.

MATERIAL AND METHODS

The research was conducted in the years 2007-2010 at the Experimental Station in Mochełek (53°13' N; 17°51' E), belonging to the University of Technology and Life Sciences in Bydgoszcz, on lessive soil, its composition being light and heavy loamy sand, bonitation class IVa, good rye complex. The two-factorial experiment was established in split-block design in four replications, plot area of 6 m × 3 m = 18 m^2. Winter wheat was sown after winter rape at the density of 5.0 million germinating grains·ha^{-1}. Raxil 02 DS dressing was applied to the seeds. Phosphate and potassic fertilizers were used in autumn before the sowing at the amount of 35 kg P·ha^{-1} and 83 kg K·ha^{-1}. Ammonium salpeter was applied once in spring (BBCH 21-23) or in divided rates: at the start of growing (BBCH 21-23), at the stage of shooting (BBCH 31-33) as well as at the stage of heading (BBCH 50-52), according to the accepted experiment scheme.

The experiment factors included:

a) cultivars:
   – Bogatka (group B),
   – Nutka (group B),
   – Kris (group B),
   – Tonacja (group A);
b) nitrogen fertilization (kg·ha^{-1}):
   – 40,
   – 80 (50 + 30),
   – 120 (60 + 40 + 20),
   – 160 (70 + 50 + 40).

Chemical weed control with Huzar 05 WG preparation (iodosulfuron-methyl-sodium + mefenpyr diethyl) was conducted in spring after the start of winter wheat growing, BBCH 27-29. Fungal diseases were controlled with Alert 375 SC preparation (flusilazole + carbendazim) at the end of the stage of shooting, BBCH 47-49. After harvest, the yield of winter wheat grain was determined. Analysis of grain quality including: weight of one thousand grains, test weight, the content and flowness of gluten, falling number, and Zeleny sedimentation index, was conducted with standard methods. Obtained results were processed statistically. Analysis of variance was conducted according to the accepted experiment scheme, and research synthesis was conducted in a mixed model design. Package of statistical programs FR – ANALWAR 5

was used for calculations. Significance of differences between the mean object quantities of analyzed traits was evaluated with Tukey test on the significance level P = 0.05.

Mean annual air temperatures at the time of research were similar to the mean value of temperature characteristic of the long-term period 1949-2007. Definitely cooler conditions, compared to the average ones, include only periods from September to November 2007 as well as from December 2009 to February 2010. From December 2007 to March 2008 visibly higher temperatures, compared to the average ones, were observed. The years of the research conduction were diversified with regard to pluvial conditions. In 2008 there was a long-term spring dry period. In May and June, there was only 27 mm of rainfall in total. However, in 2009 large deficiencies of rainfall (27.4 mm), compared to the average ones, occurred in April. The growing season in 2010 was rich in rainfall, but its distribution was not favorable for the cereals. Large deficiency of rainfall (36 mm), compared to the long-term mean value, occurred in June. On the other hand, great total rainfall was observed in May, July and August (Table 1).

RESULTS

The yield of winter wheat grain cultivated on light soil depended on the cultivar and nitrogen fertilization. The highest yield was obtained from Kris cultivar. Its grain yield was significantly greater than that of Bogatka and Tonacja cultivars, by 8.2%, as well as that of Nutka, by 9.4% (Table 2). The factor which significantly affected the grain yield was also nitrogen fertilization. Increasing the rate from 40 to 80 kg $N \cdot ha^{-1}$ caused the increase of the grain yield by 14.4%. Greater fertilization did not however result in a significant yield increase. The yields of studied winter wheat cultivars depending on nitrogen fertilization were similar. Studied factors of agricultural techniques, that is cultivar and nitrogen fertilization, independently influenced both the yield and the grain quality (Table 3).

The effect of cultivar on the technological value of the winter wheat grain was significant but different on its particular parameters (Table 3). Grain of Bogatka, Nutka and Tonacja cultivars was characterized by a greater content of wet gluten and its flowness than the grain of Kris cultivar. The greatest weight of one thousand grains (43.4 g) was characteristic of Bogatka cultivar. The mean grain density in weight test was 74.9 $kg \cdot hl^{-1}$, and the proved differences in the quantity of this parameter occurred between Tonacja and Nutka and Kris cultivars. On the other hand, with regard to the falling number, more favorable was the grain quality of Kris and Bogatka cultivars in relation to Tonacja and Nutka cultivars. Grain of Nutka cultivar was characterized by the greatest sedimentation index, 57.1 s. Lower value of this trait occurred in Tonacja and Bogatka cultivars, and the lowest in Kris cultivar, 39.7 s.

Nitrogen fertilization significantly, though similarly in particular cultivars, influenced quality parameters of winter wheat grain (Table 3). The content of wet gluten increased significantly together with the increase of its rate by every subsequent 40 kg $N \cdot ha^{-1}$. It was from 20.8%, as a result of application of the lowest nitrogen rate, to 32.9%, after application of 160 kg $N \cdot ha^{-1}$. However, greater flowness of wet gluten was found only after the increase of nitrogen fertilization from 40 to 160 kg $N \cdot ha^{-1}$. Together with the increase of fertilization from 40 to 120 and 160 kg $N \cdot ha^{-1}$ also the falling number increased, and from 40 to 80 kg $N \cdot ha^{-1}$ and higher rates, sedimentation index increased. The quantity of nitrogen fertilization rate did not differentiate significantly the physical quality traits, that is the weight of one thousand seeds and test weight of winter wheat grain.

Table 1. Weather conditions in 2007-2010
Tabela 1. Warunki opadowo-termiczne w latach 2007-2010

Lata Years	Month – Miesiąc											
	September wrzesień	October październik	November listopad	December grudzień	January styczeń	February luty	March marzec	April kwiecień	May maj	June czerwiec	July lipiec	August sierpień
	Temperature – Temperatura, °C											
2007/2008	12.4	6.9	1.3	0.3	0.5	2.8	3.0	7.6	13.2	17.6	19.2	17.8
2008/2009	12.4	8.4	4.3	0.2	-3.3	-0.9	2.4	9.8	12.3	14.5	18.6	18.2
2009/2010	13.7	6.3	5.2	-1.1	-7.8	-2.7	2.4	7.8	11.5	16.7	21.6	18.4
1949-2007	13.2	8.2	3.0	-0.5	-2.3	-1.5	1.8	7.3	12.8	16.2	18.0	17.4
	Rainfall – Opady, mm											
2007/2008	37.6	19.9	22.3	36.0	48.2	15.9	61.2	38.7	11.5	15.5	58.7	95.5
2008/2009	20.2	80.0	19.4	24.8	14.2	19.4	43.7	0.4	85.3	57.4	118.0	17.6
2009/2010	34.4	66.2	40.4	35.4	22.0	20.1	28.6	33.8	92.6	18.1	107.4	150.7
1949-2007	41.4	31.9	31.8	31.7	24.0	19.2	23.7	27.8	42.2	54.1	71.0	51.2

Table 2. Grain yield of winter wheat, t·ha^{-1} (2008-2010)
Tabela 2. Plon ziarna pszenicy ozimej, t·ha^{-1} (2008-2010)

Cultivar – Odmiana (A)	Nitrogen fertilization – Nawożenie azotowe (B) kg N·ha^{-1}				Mean – Średnia
	40	80	120	160	
Bogatka	4.20	4.73	4.78	4.82	4.63
Nutka	4.15	4.67	4.77	4.75	4.58
Kris	4.60	5.15	5.19	5.09	5.01
Tonacja	3.99	4.80	4.93	4.82	4.63
Mean – Średnia	4.23	4.84	4.92	4.87	4.71
$LSD_{0.05}$ – $NIR_{0,05}$	A 0.28	B 0.23	other – pozostałe	ns – ni	

ns – ni – non-significant differences – różnice nieistotne

Table 3. Technological quality of winter wheat grain depending on cultivar and nitrogen fertilization (2008-2010)
Tabela 3. Jakość technologiczna ziarna pszenicy ozimej w zależności od odmiany i nawożenia azotem (2008-2010)

Cultivar – Odmiana (A)	Nitrogen fertilization – Nawożenie azotowe (B) kg N·ha^{-1}				Mean – Średnia
	40	80	120	160	
1	2	3	4	5	6
Gluten content – Zawartość glutenu, %					
Bogatka	21.3	26.8	31.7	34.4	28.6
Nutka	21.5	25.0	32.2	35.5	28.5
Kris	18.7	20.4	24.5	27.9	22.9
Tonacja	21.8	26.3	30.1	33.9	28.0
Mean – Średnia	20.8	24.6	29.6	32.9	27.0
$LSD_{0.05}$ – $NIR_{0,05}$	A 3.3	B 2.6	other – pozostałe	ns – ni	
Flowness of gluten – Rozpływalność glutenu, mm					
Bogatka	4.3	6.7	6.3	6.3	5.9
Nutka	5.7	6.7	8.3	8.3	7.3
Kris	4.3	3.7	4.7	4.7	4.3
Tonacja	7.0	5.3	7.0	8.3	6.9
Mean – Średnia	5.3	5.6	6.6	6.9	6.1
$LSD_{0.05}$ – $NIR_{0,05}$	A 1.7	B 1.5	other – pozostałe	ns – ni	
Weight of 1000 grains – Masa 1000 ziaren, g					
Bogatka	44.2	42.8	43.9	42.6	43.4
Nutka	39.7	38.4	41.1	39.8	39.7
Kris	40.3	38.9	38.2	37.8	38.8
Tonacja	39.1	40.6	38.9	39.7	39.6
Mean – Średnia	40.8	40.2	40.5	40.0	40.4
$LSD_{0.05}$ – $NIR_{0,05}$	A 1.4	B ns – ni	other – pozostałe	ns – ni	
Test weight – Masa hektolitra, kg·hl^{-1}					
Bogatka	75.2	75.5	74.3	75.5	75.1
Nutka	74.2	73.9	73.4	73.4	73.7
Kris	75.2	74.6	73.8	73.0	74.2
Tonacja	76.6	76.7	76.4	75.9	76.4
Mean – Średnia	75.3	75.2	74.5	74.4	74.9
$LSD_{0.05}$ – $NIR_{0,05}$	A 1.4	B ns – ni	other – pozostałe	ns – ni	

Table 3 continue – cd. tabeli 3

1	2	3	4	5	6
Falling number – Liczba opadania, s					
Bogatka	297	345	376	367	346
Nutka	251	264	280	273	267
Kris	349	389	366	410	378
Tonacja	252	275	292	274	273
Mean – Średnia	287	318	328	331	316
$LSD_{0.05}$ – $NIR_{0,05}$	A 52	B 32	other – pozostałe	ns – ni	
Zeleny sedimentation index – Wskaźnik sedymentacji Zeleny'ego, cm^3					
Bogatka	35.0	46.3	51.0	51.7	46.0
Nutka	43.0	54.3	64.3	66.7	57.1
Kris	31.7	36.0	42.7	48.3	39.7
Tonacja	38.7	45.3	56.0	59.0	49.7
Mean – Średnia	37.1	45.5	53.5	56.4	48.1
$LSD_{0.05}$ – $NIR_{0,05}$	A 5.5	B 7.7	other – pozostałe	ns – ni	

ns – ni – non-significant differences – różnice nieistotne

DISCUSSION

The yield of winter wheat cultivated in Poland under favorable habitat conditions, especially with intensive agricultural techniques, reaches the level of 8-10 $t \cdot ha^{-1}$ [Lista opisowa… 2009, Wyniki… 2007, 2009]. In own research the yield was 4.71 $t \cdot ha^{-1}$, which confirms a well-known fact concerning limited possibility of manifestation of the production potential of this plant on light soil. Under these conditions, as is indicated in the results of earlier studies by Kuś and Siuta [1995] and Rudnicki [2005], there is a greater dependence of the wheat yield on the level of agricultural techniques and weather conditions.

Confirmed small increases of the winter wheat yield, as a result of the increase of nitrogen rate from 40 to 160 kg $N \cdot ha^{-1}$, may result from unfavorable rainfall conditions in 2008 and 2010, which reduced manifestation of the yield-producing effect of nitrogen. Depending on the soil-climatic conditions and agricultural techniques, it is observed that there occurs the increase of the winter wheat yield under the influence of nitrogen fertilization, similarly to own research, to the rate of 80 kg $N \cdot ha^{-1}$ [Jończyk 1995, Stankowski et al. 2004, Piekarczyk 2010b], but also to 120 kg $N \cdot ha^{-1}$ [Knapowski and Ralcewicz 2004] or greater [Rutkowska 2002, Podolska et al. 2007]. Exceeding the optimum nitrogen rate for the yield often has a favourable effect on the technological quality of the wheat grain [Knapowski and Ralcewicz 2004, Mazurkiewicz and Bojarczyk 2004, Stankowski et al. 2004, Podolska et al. 2007]. In own research the best parameters of quality and technological value of the grain were obtained after application of rates greater than 80 kg $N \cdot ha^{-1}$. According to many authors, obtaining high quality parameters of wheat grain, requires, apart from intensive agricultural techniques, also optimum weather conditions [Podolska and Sułek 2002, Mazurkiewicz and Bojarczyk 2004]. Grain collected in the years 2008-2010 was characterized by relatively low technological quality. It may have resulted from generally higher than the long-term mean amount of rainfall in the period of maturation and of winter wheat harvest. Although the grain fulfilled the criteria of intervention purchase of cereals

[Wymagania jakościowe...] in reference to the test weight (min. 73 kg·hl^{-1}), falling number (min. 220 s) and sedimentation index (min. 22 cm^3), it did not however correspond to the standards established for the Polish mills [Sitkowski 2010] with regard to the grain density (min. 77 kg·hl^{-1}) as well as the content of wet gluten (min. 27%). These standards were not satisfied by the grain obtained as a result of application of 40 and 80 kg N·ha^{-1} and of Kris cultivar cultivation. This cultivar belongs to the productive ones, but under favorable soil conditions its predominance over other cultivars does not exceed 5% [Wyniki… 2007, 2009]. In own research this difference was slightly higher. Despite the relatively high yield, the grain of Kris cultivar was characterized by the lowest technological quality, especially with regard to the content of wet gluten and sedimentation index. It corresponds to the research results on the quantity and quality of yield of many other cultivars [Lista opisowa… 2009].

CONCLUSIONS

1. Cultivar and nitrogen fertilization proved to be significant elements of agricultural techniques, having an independent influence and affecting the yield and quality of the winter wheat grain on the light soil.

2. Under soil conditions not very favourable for winter wheat and in the region and years of relatively low amounts of rainfall in its growing season, nitrogen fertilization over 80 kg N·ha^{-1} did not significantly increase the grain yield, but favourably affected many traits of its technological value, especially the gluten content and sedimentation index.

3. Among compared winter wheat cultivars, the highest yield was obtained from Kris cultivar. However, its grain was characterized by the lowest technological quality.

REFERENCES

Blecharczyk A., Śpitalniak J., Małecka I., 2006. Wpływ doboru przedplonów oraz systemów uprawy roli i nawożenia azotem na plonowanie pszenicy ozimej [The effect of forecrop selection as well as of cultivation systems and nitrogen fertilization on the yield of winter wheat]. Fragm. Agron. 2(90), 273-286 [in Polish].

Fotyma E., 2003. Porównanie produktywności pszenicy ozimej uprawianej w różnych warunkach agroekologicznych [Comparison of productivity of winter wheat cultivated in different agroecological conditions]. Fragm. Agron. 3(79), 98-114 [in Polish].

Jończyk K., 1995. The influence of several agrotechnical factors on winter wheat yields. Fragm. Agron. 2(46), 184-185 [in Polish].

Knapowski T., Ralcewicz M., 2004. Ocena wskaźników jakościowych ziarna mąki pszenicy ozimej w zależności od zróżnicowanego nawożenia azotem [Evaluation of quality indexes of grain of winter wheat flour depending on diversified nitrogen fertilization]. Ann. Univ. Mariae Curie-Skłodowska, Sect. E, Agricultura 59(2), 959-968 [in Polish].

Kuś J., Siuta A., 1995. Plonowanie zbóż ozimych w zależności od przedplonu i kompleksu glebowego [Yield of winter cereals depending on the forecrop and soil complex]. Fragm. Agron. 3(47), 53-58 [in Polish].

Lista opisowa odmian 2008 [Descriptive list of cultivars 2008], 2009. Rośliny rolnicze. Część 1. Zbożowe [Agricultural crops. Part 1. Cereal crops]. COBORU Słupia Wielka [in Polish].

Mazurkiewicz J., Bojarczyk M., 2004. Wpływ zróżnicowanego nawożenia azotem na jakość technologiczną odmian pszenicy ozimej uprawianych w monokulturze [Effect of diversified nitrogen fertilization on the technological quality of winter wheat cultivars grown in monoculture]. Ann. Univ. Mariae Curie-Skłodowska, Sect. E, Agricultura 59(4), 1621-1629 [in Polish].

Piekarczyk M., 2007. Wartość przedplonowa łubinu wąskolistnego i jęczmienia jarego dla pszenicy ozimej w zależności od sposobu odchwaszczania łanu [The forecrop quality of blue lupin and spring rye for winter wheat depending on the weed control system of the canopy]. Acta Sci. Pol., Agricultura 6(3), 59-67 [in Polish].

Piekarczyk M., 2010a. Effect of fertilisation dose, plant protection and seeding density on the yield and grain technological quality of winter wheat grown in short-time monoculture on light soil. Acta Sci. Pol., Agricultura 9(2), 15-23 [in Polish].

Piekarczyk M., 2010b. Effect of forecrops and nitrogen fertilisation on the yield and grain technological quality of winter wheat grown on light soil. Acta Sci. Pol., Agricultura 9(2), 25-33.

Podolska G., Stankowski S., Dworakowski T., 2007. Wpływ dawki nawożenia azotem na wielkość plonu i wartość technologiczną ziarna pszenicy ozimej [Effect of nitrogen fertilization rate on the yield quantity and grain technological value of winter wheat]. Fragm. Agron. 2(94), 274-282 [in Polish].

Podolska G., Sułek A., 2002. Główne elementy technologii produkcji decydujące o wysokiej jakości ziarna pszenicy [Main elements of production technology determining high quality of wheat grain]. Pam. Puł. 130, 597-605 [in Polish].

Rudnicki F., 2005. Przedplony zbóż a ich plonowanie w warunkach produkcyjnych [Cereal forecrops and their yield under production conditions]. Fragm. Agron. 2(86), 172-182 [in Polish].

Rutkowska A., 2002. Efektywność późnych dawek azotu w nawożeniu pszenicy jakościowej [Effectiveness of late nitrogen rates in bread wheat fertilization]. Pam. Puł. 130, 647-652 [in Polish].

Sitkowski T., 2010. Zboże dla młynów. Wymagania co do jakości zboża przeznaczonego na mąkę [Cereals for mills. Requirements concerning quality of the cereals intended for flour]. www.ihar.edu.pl [in Polish].

Stankowski S., Podolska G., Pacewicz K., 2004. Wpływ nawożenia azotem na plonowanie i jakość ziarna odmian pszenicy ozimej [Effect of nitrogen fertilization on the yield and quality of the grain of winter wheat cultivars]. Ann. Univ. Mariae Curie-Skłodowska, Sect. E, Agricultura 59(3), 1363-1369 [in Polish].

Wymagania jakościowe dla zbóż objętych interwencyjnym zakupem [Quality requirements for cereals included in the intervention purchase]. www.arr.gov.pl [in Polish].

Wyniki porejestrowych doświadczeń odmianowych 2006 [Results of postregistration experiments 2006], 2007. Zboża ozime 46 [Winter cereals 46]. COBORU Słupia Wielka [in Polish].

Wyniki porejestrowych doświadczeń odmianowych 2008 [Results of postregistration experiments 2006], 2009. Zboża ozime 64 [Winter cereals 64]. COBORU Słupia Wielka [in Polish].

WPŁYW NAWOŻENIA AZOTEM NA PLONOWANIE I JAKOŚĆ TECHNOLOGICZNĄ ZIARNA WYBRANYCH ODMIAN PSZENICY OZIMEJ UPRAWIANYCH NA GLEBIE LEKKIEJ

Streszczenie. W doświadczeniu polowym, przeprowadzonym w latach 2007-2010 w Mochełku (53°13’ N; 17°51’ E) koło Bydgoszczy na glebie kompleksu żytniego dobrego, oceniano wpływ nawożenia azotem (40, 80, 120, 160 kg $N \cdot ha^{-1}$) na plonowanie i jakość technologiczną ziarna pszenicy ozimej odmian Bogatka, Nutka, Kris, Tonacja. Stwierdzono, że w agrotechnice pszenicy ozimej na glebie lekkiej odmiana i nawożenie azotem

są elementami oddziałującymi niezależnie. W tych warunkach glebowych i rejonie oraz latach o relatywnie niskich sumach opadów w okresie wegetacji, nawożenie azotem powyżej 80 kg $N \cdot ha^{-1}$ nie zwiększało istotnie plonu ziarna, ale wpływało korzystnie na jego wartość technologiczną. Spośród porównywanych odmian pszenicy ozimej najlepiej plonowała odmiana Kris. Ziarno tej odmiany miało jednak najniższą jakość technologiczną.

Słowa kluczowe: liczba opadania, rozpływalność glutenu, wskaźnik sedymentacji Zeleny'ego, zawartość glutenu

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