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EFFECT OF FORECROPS AND NITROGEN FERTILISATION ON THE YIELD AND GRAIN TECHNOLOGICAL QUALITY OF WINTER WHEAT GROWN ON LIGHT SOIL

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Abstract. In a field experiment in years 2007-2009 at Mochełek (53°13' N; 17°51' E) near Bydgoszcz on good rye complex soil, the effect of forecrop (spring barley, blue lupine, blue lupine + spring triticale, spring rape) and nitrogen fertilisation (40, 80, 120, and 160 kg N·ha^{-1}) on the yield and grain technological quality of winter wheat cultivar Tonacja was estimated. It was stated in the research that significant elements in the agronomical practices of winter wheat grown on light soil, although affecting independently, are forecrop and nitrogen fertilisation. Grain yield and its quality on a worse stand cannot be improved by increased fertilisation. The most favourable stand for winter wield yield was blue lupine in pure sowing. Spring rape, and also a mixture of lupine with spring triticale and spring barley were worse forecrops than blue lupine. On light soil in region and years with relatively low precipitation sums during the growth period, independently of forecrop, nitrogen fertilisation above 80 kg N·ha^{-1} did not increase significantly grain yield but affected positively its technological quality.

Key words: blue lupine, falling number, gluten content, sedimentation index, spring rape, test weight

INTRODUCTION

Growing winter wheat on light soils is more unreliable, and yield to a higher degree than on medium and heavy soils depends on forecrop and weather conditions [Kuś and Siuta 1995, Rudnicki 2005]. Stand has great significance for winter wheat development and may modify also the effect of the used fertilisers [Blecharczyk et al. 1995, 2006]. Nitrogen fertilisation has a particularly clear effect on the formation of grain yield size and quality [Podolska and Sułek 2002, Fotyma 2003], and in unfavourable habitat conditions, the choice of forecrop plant gains a greater significance [Harasimowicz-

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-Hermann 1997, Piekarczyk 2007]. Even though the effect of both of these factors may be considered well-recognized, it seems necessary to determine their interaction, particularly with light soil.

It is assumed that forecrop may modify the effectiveness of nitrogen fertilisation and its effect on the technological value of wheat grain.

The aim of the study was the determination of an independent and interactive effect of forecrop and nitrogen fertilisation on the grain yield and quality of winter wheat cultivar Tonacja grown on light soil.

MATERIAL AND METHODS

Research was conducted in years 2007-2009 at the Research Station at Mochełek (53°13' N; 17°51' E), which is part of the University of Technology and Life Sciences in Bydgoszcz, on lessives composed of light and heavy loamy sand, quality class IVa, good rye complex. Strict two-factor field experiment was set up as a split-block design in four replications, with plot size 6 x 3 = 18 m^2. Winter wheat cultivar Tonacja was sown after earlier prepared forecrops at the density of 5.0 million germinating grains·ha^{-1}. Grain was fungicide treated with Raxil 02 DS. Phosphorus and potassium fertilisers were applied in autumn before seeding in the amount of 35 kg P·ha^{-1} and 83 kg K·ha^{-1}. Ammonium nitrate was sown in spring in a single dose or in split doses at the onset of growth, during straw shooting phase, and during earing, according to the accepted experiment scheme.

The experiment included the following factors:

I) forecrop (in parentheses – grain and seed yields):
- spring barley (3.68 t·ha^{-1}),
- blue lupine (2.42 t·ha^{-1}),
- blue lupine + spring triticale (3.97 t·ha^{-1}),
- spring rape (2.36 t·ha^{-1});

II) nitrogen fertilisation in kg·ha^{-1} (in parentheses – dose distribution):
- 40,
- 80 (50 + 30),
- 120 (60 + 40 + 20),
- 160 (70 + 50 + 40).

Chemical weeding with Huzar 05 WG (iodosulphuron methylsodium + mefenpyr-diethyl) was performed in the spring after the onset of winter wheat growth, whereas fungous diseases controlling took place a single time with fungicide Alert 375 SC (flusilazole + carbendazim) at the end of straw shooting phase. After harvest, winter wheat grain yield was estimated. Standard methods were used for the analysis of wheat grain quality: gluten content and flowness, test weight (hectolitre), falling number, and Zeleny sedimentation index.

The results were processed using the analysis of variance with the application of the software developed at the University of Technology and Life Sciences in Bydgoszcz by Rudnicki, based on Excel 97-2003. To valuate the significance of the differences of means for the particular items, the Tukey's test was applied at the significance level of P = 0.05.

Average annual air temperatures in the study period were similar to the value of the mean temperature characteristic for the 1949-2007 period. Significantly warmer compared to the average conditions were only periods from October 2006 to March 2007 and from December 2007 to March 2008. Years of the experiment were diversified in regard to pluvial conditions. In 2007, small precipitation shortages occurred in April, whereas in May and June precipitation sums were higher in comparison with the average conditions of the may years' period, which was conducive to obtaining higher winter wheat grain yield. In 2008, a long-lasting spring drought occurred, with only 27 mm of rain in May and June. On the other hand, in 2009 large precipitation shortages (-27.4 mm) in comparison with the average conditions occurred in April (Table 1).

RESULTS AND DISCUSSION

The research did not confirm any interaction between forecrop and nitrogen fertilisation dose on the quality and size of winter wheat grain yield. However, a significant effect of forecrop on winter wheat yield was stated. Grain yield on the stand after lupine was higher than yields after spring rape, spring barley, and the mixture of blue lupine and spring triticale (Table 2). In addition, a proven difference in wheat grain yield between the forecrops of spring rape and the mixture of blue lupine with spring triticale was found. Increase in nitrogen fertilisation from 40 to 80 kg $N \cdot ha^{-1}$ caused a significant increase in winter wheat grain yield by 6.4%. Further increase in nitrogen dose from 80 to 120 and 160 kg $N \cdot ha^{-1}$ resulted only in a statistically unproven tendency for grain yield to increase (Table 2).

No significant differences were found in the technological value of winter wheat grain depending on forecrop (Table 3). Winter wheat grain, regardless of forecrop, met the criteria of grain intervention purchase [Quality requirements...]. Grain technological value was formed by nitrogen fertilisation. The content of wet gluten increased with the nitrogen dose. After the application of 120 and 160 kg $N \cdot ha^{-1}$, it was significantly higher than as a result of the application of 40 kg $N \cdot ha^{-1}$ (Table 4). Significant differences in this parameter were also stated between the doses of 80 kg $N \cdot ha^{-1}$ (24.3%) and 160 kg $N \cdot ha^{-1}$ (33.2%). Increase in the nitrogen fertilisation dose above 40 kg $N \cdot ha^{-1}$ caused a small increase in the flowness of gluten. The experiment also proved an increase in the falling number with the increase in the nitrogen dose above 40 kg ha^{-1}, and a significant increase in the sedimentation index was observed from the dose of 80 kg $N \cdot ha^{-1}$. Nitrogen fertilisation dose did not differentiate significantly the weight of 1000 grains or winter wheat grain test weight (hectolitre).

Table 1. Weather conditions in 2006-2009
Tabela 1. Warunki opadowo-termiczne w latach 2006-2009

Year Rok	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											
2006-2007	15.2	9.6	5.2	3.7	2.7	-1.0	5.0	8.5	13.8	18.2	18.0	17.8
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
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											
2006-2007	40.6	12.1	33.9	31.4	75.9	28.0	47.9	17.6	73.1	105.5	104.7	42.1
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
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. Winter wheat grain yield, $t \cdot ha^{-1}$ (2007-2009)
Tabela 2. Plon ziarna pszenicy ozimej, $t \cdot ha^{-1}$ (2007-2009)

Forecrop – Przedplon (A)	Nitrogen fertilisation – Nawożenie azotowe (B) kg $N \cdot ha^{-1}$				Mean Średnia
	40	80	120	160	
Spring barley – jęczmień jary	4.53	4.77	4.88	5.17	4.84
Blue lupine – łubin wąskolistny	5.20	5.45	5.74	5.46	5.46
Blue lupine + spring triticale Łubin wąskolistny + pszenżyto jare	4.44	4.65	4.82	4.95	4.71
Spring rape – rzepak jary	4.67	5.15	5.30	5.23	5.09
Mean – Średnia	4.71	5.01	5.18	5.20	5.02
$LSD_{0.05}$ – $NIR_{0,05}$ A 0.29 B 0.24	other – pozostałe ns – ni				

ns – ni – non-significant – nieistotne

Table 3. Technological quality of winter wheat grain depending on forecrop (2007-2009)
Tabela 3. Jakość technologiczna ziarna pszenicy ozimej w zależności od przedplonu (2007-2009)

Specification Wyszczególnienie	Forecrop – Przedplon				Mean Średnia	$LSD_{0.05}$ $NIR_{0,05}$
	spring barley jęczmień jary	blue lupine łubin wąskolistny	blue lupine + spring triticale łubin wąskolistny + pszenżyto jare	spring rape rzepak jary		
Gluten content, % Zawartość glutenu	28.3	27.2	26.8	26.6	27.2	ns – ni
Flowness of gluten, mm Rozpływalność glutenu	6.42	6.25	6.58	6.92	6.54	ns – ni
Weight of 1000 grains, g Masa 1000 ziaren	38.5	40.1	38.4	39.9	39.2	ns – ni
Test weight, $kg \cdot hl^{-1}$ Masa hektolitra	76.9	77.5	76.3	77.3	77.0	ns – ni
Falling number, s Liczba opadania	281	275	287	265	277	ns – ni
Zeleny sedimentation index, cm^3 Wskaźnik sedymentacji Zeleny'ego	54.3	53.2	52.3	52.1	53.0	ns – ni

ns – ni – non-significant – nieistotne

In the experiment, a significantly favourable effect, compared with the other forecrops, of blue lupine stand on winter wheat was found. The scale of this interaction is usually characterised by seasonal changeability, which depends on the amount and distribution of precipitation and is more clear in the conditions of lower quality soils and higher lupine seeding density [Rudnicki and Kotwica 1994, Kuś and Siuta 1995, Rudnicki 2005]. Legumes as forecrop have a very favourable effect on winter wheat, which is widely confirmed in literature. Clear increase in grain yield, in the range from 0.5 to 2.48 $t \cdot ha^{-1}$ was found after the following forecrops: pea [Kuś and Siuta 1995, Suwara and Gawrońska-Kulesza 1995, Blecharczyk et al. 1995, 2006], horse bean [Blecharczyk et al. 1995, 2006, Harasimowicz-Hermann 1997], soya [Blecharczyk et al. 1995, 2006], and lupine [Rudnicki and Kotwica 1994, Kuś and Siuta 1995, Piekarczyk 2007]. Positive effect of the stand on cereals after legumes results from both the nitrogen left in the soil and the improvement in the physico-chemical properties of the soil, infestation limitation, and pathogen occurrence. As a result, wheat is characterised by a greater number of spikes per area unit; spike grain weight and number, as well as the weight of 1000 grains are also more favourable [Blecharczyk et al. 1995, 2006]. The experiment additionally confirmed a positive in comparison with cereal forecrops effect of ripe on winter wheat [Harasimowicz-Hermann 1997, Szczebiot and Ojczyk 2002]. Relatively the worst stand for winter wheat in the present study turned out to be the cereal-legume mixture of spring triticale and blue lupine. This probably results from the fact that triticale sown at the density of 500 plants·m^{-2} dominated too much lupine sown at the density of 80 plants·m^{-2}. Greater participation of cereal plant in the mixture is conducive to obtaining higher yields but causes a decrease in the participation of lupine in the plant mixture, which is less competitive in relation to cereals [Rudnicki and Kotwica 1994, Rudnicki 1997, Rudnicki and Gałęzewski 2007]. Spring triticale domination in the mixture caused a prevalence of negative effect of this cereal on winter wheat [Rudnicki and Kotwica 1994, Harasimowicz-Hermann 1997].

Table 4. Technological quality of winter wheat grain depending on nitrogen fertilisation (2007--2009)
Tabela 4. Jakość technologiczna ziarna pszenicy ozimej w zależności od nawożenia azotem (2007-2009)

Specification Wyszczególnienie	Nitrogen fertilisation – Nawożenie azotowe kg N·ha^{-1}				Mean Średnia	$LSD_{0.05}$ $NIR_{0,05}$
	40	80	120	160		
Gluten content, % Zawartość glutenu	20.9	24.3	30.5	33.2	27.2	6.6
Flowness of gluten, mm Rozpływalność glutenu	4.83	6.75	6.75	7.83	6.54	1.43
Weight of 1000 grains, g Masa 1000 ziaren	39.1	39.4	39.2	39.1	39.2	ns – ni
Test weight, kg·hl^{-1} Masa hektolitra	76.4	76.9	77.3	77.5	77.0	ns – ni
Falling number, s Liczba opadania	243	263	293	308	277	20.0
Zeleny sedimentation index, cm^3 Wskaźnik sedymentacji Zeleny'ego	43.0	48.0	58.8	62.3	53.0	6.6

ns – ni – non-significant – nieistotne

Nitrogen fertilisation is one of the more important yield-forming factors. Relatively small increase in wheat grain yield observed in the present study as a result of an increase in the nitrogen dose from 40 to 160 kg N·ha^{-1} may probably result from very unfavourable precipitation conditions in 2008, which made it more difficult to fully develop the yield-forming properties of nitrogen, as well as from the fact of poor use in that particular year of nitrogen by the plants that were forecrops for winter wheat. In the present study, an increase in winter wheat grain yield to the dose of 80 kg N·ha^{-1} was proven. Depending on the soil and weather conditions, as well as on the cultivar, an increase in winter wheat yield to the dose of 80 kg N·ha^{-1} may be observed [Jończyk 1995, Stankowski et al. 2004], 120 kg N·ha^{-1} [Knapowski and Ralcewicz 2004], or even higher ones [Rutkowska 2002, Podolska et al. 2007]. Exceeding the nitrogen dose above the optimum one, from the point of view of field size, has, however, a favourable effect on wheat grain technological quality [Knapowski and Ralcewicz 2004, Mazurkiewicz and Bojarczyk 2004, Stankowski et al. 2004, Podolska et al. 2007]. Obtainment of the desirable, high quality parameters of wheat grain requires the application of intensive agronomical practices and optimum weather course [Podolska and Sułek 2002, Mazurkiewicz and Bojarczyk 2004].

CONCLUSIONS

1. Significant elements in the agronomical practices of winter wheat grown on light soil, although affecting independently, are forecrop and nitrogen fertilisation. Grain yield and quality on a worse stand may not, therefore, be improved by increased fertilisation.
2. The most favourable stand for winter wheat yield was blue lupine in pure sowing. Spring rape, and especially the mixture of lupine and spring triticale, as well as spring barley, were worse forecrops.
3. On light soil in region and years with relatively low precipitation sums during the growth period, independently of forecrop, nitrogen fertilisation above 80 kg $N \cdot ha^{-1}$ did not increase significantly grain yield but affected favourably its technological quality.

REFERENCES

Blecharczyk A., Skrzypczak G., Śpitalniak J., 1995. Response of winter wheat to previous crops and nitrogen fertilisation. Fragm. Agron. 2(46), 236-237.

Blecharczyk A., Śpitalniak J., Małecka I., 2006. Wpływ doboru przedplonów oraz systemów uprawy roli i nawożenia azotem na plonowanie pszenicy ozimej [Effect of forecrop choice, tillage systems, and nitrogen fertilisation on winter wheat yield]. Fragm. Agron. 2(90), 273-286 [in Polish].

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

Harasimowicz-Hermann G., 1997. Wartość przedplonowa bobiku, zbóż i ich mieszanek dla pszenicy ozimej w warunkach regionu pomorsko-kujawskiego [Forecrop value of horse bean, cereals, and their mixtures for winter wheat in the conditions of the Pomeranian-Kuyavian region]. Zesz. Probl. Post. Nauk Rol. 446, 369-375 [in Polish].

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

Knapowski T., Ralcewicz M., 2004. Ocena wskaźników jakościowych ziarna mąki pszenicy ozimej w zależności od zróżnicowanego nawożenia azotem [Assessment of the quality indicators of winter wheat grain flour in regard to diversified nitrogen fertilisation]. 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 [Winter wheat yield depending on forecrop and soil complex]. Fragm. Agron. 3(47), 53-58 [in Polish].

Mazurkiewicz J., Bojarczyk M., 2004. Wpływ zróżnicowanego nawożenia azotem na jakość technologiczną odmian pszenicy ozimej uprawianych w monokulturze [Effect of diversified nitrogen fertilisation 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 [Forecrop value of blue lupine and spring barley for winter wheat depending on lowland meadow weeding method]. Acta Sci. Pol., Agricultura 6(3), 59-67 [in Polish].
Podolska G., Stankowski S., Dworakowski T., 2007. Wpływ dawki nawożenia azotem na wielkość plonu i wartość technologiczną ziarna pszenicy ozimej [Effect of nitrogen fertilisation dose on the yield size and grain technological quality 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 production technology elements that decide about high quality of wheat grain]. Pam. Puł. 130, 597-605 [in Polish].
Rudnicki F., 1997. Potencjalna przydatność odmian łubinu żółtego i wąskolistnego do mieszanek ze zbożami jarymi [Potential usefulness of yellow and blue lupine cultivars for mixtures with spring cereals]. Zesz. Probl. Post. Nauk Rol. 446, 407-413 [in Polish].
Rudnicki F., 2005. Przedplony zbóż a ich plonowanie w warunkach produkcyjnych [Cereal forecrops and their yield in production conditions]. Fragm. Agron. 2(86), 172-182 [in Polish].
Rudnicki F., Gałęzewski L., 2007. Reakcje owsa i łubinu żółtego na uprawę w mieszankach o różnym składzie ilościowym oraz efekty produkcyjne uprawy mieszanek [Reactions of oats and yellow lupine to cultivation in mixtures with different quantitative compositions and production effects of mixture cultivation]. Zesz. Probl. Post. Nauk Rol. 516, 171-179 [in Polish].
Rudnicki F., Kotwica K., 1994. Wartość przedplonowa pszenżyta jarego, łubinu żółtego i ich mieszanek dla pszenicy ozimej [Forecrop value of spring triticale, yellow lupine, and their mixtures for winter wheat]. Fragm. Agron. 2(42), 19-24 [in Polish].
Rutkowska A., 2002. Efektywność późnych dawek azotu w nawożeniu pszenicy jakościowej [Effectiveness of late nitrogen doses in quality wheat fertilisation]. Pam. Puł. 130, 647-652 [in Polish].
Stankowski S., Podolska G., Pacewicz K., 2004. Wpływ nawożenia azotem na plonowanie i jakość ziarna odmian pszenicy ozimej [Effect of nitrogen fertilisation on the grain yield and quality of winter wheat cultivars]. Ann. Univ. Mariae Curie-Skłodowska, Sect. E, Agricultura 59(3), 1363-1369 [in Polish].
Suwara I., Gawrońska-Kulesza A., 1995. Yielding and yield structure of winter wheat (*Triticum aestivum*) after different forecrops depending on rate of nitrogen fertilisation. Fragm. Agron. 2(46), 216-217.
Szczebiot M., Ojczyk T., 2002. Wartość nawozowa resztek pożniwnych jarych roślin oleistych dla pszenicy ozimej [Fertilising value of the post-harvest residue of spring oilseed plants for winter wheat]. Fragm. Agron. 2(74), 198-206 [in Polish].
Wymagania jakościowe dla zbóż objętych interwencyjnym zakupem [Quality requirements for cereals included in intervention purchase]. www.arr.gov.pl [in Polish].

WPŁYW PRZEDPLONU I NAWOŻENIA AZOTEM NA PLONOWANIE I JAKOŚĆ TECHNOLOGICZNĄ ZIARNA PSZENICY OZIMEJ UPRAWIANEJ NA GLEBIE LEKKIEJ

Streszczenie. W doświadczeniu polowym przeprowadzonym w latach 2007-2009 w Mochełku (53°13’ N; 17°51’ E) koło Bydgoszczy na glebie kompleksu żytniego dobrego oceniano wpływ przedplonu (jęczmienia jarego, łubinu wąskolistnego, łubinu wąskolistnego + pszenżyta jarego, rzepaku jarego) i nawożenia azotem (40, 80, 120, 160 kg N·ha^{-1}) na plonowanie i jakość technologiczną pszenicy ozimej odmiany Tonacja. W badaniach stwierdzono, że istotnymi elementami w agrotechnice pszenicy ozimej na glebie lekkiej, oddziałującymi jednak niezależnie, są przedplon i nawożenie azotem.

Plonu ziarna i jego jakości w słabszym stanowisku nie można poprawić przez zwiększenie nawożenia. Najkorzystniejszy wpływ na plonowanie pszenicy ozimej miał łubin wąskolistny w siewie czystym. Rzepak jary, a także mieszanka łubinu z pszenżytem jarym oraz jęczmień jary były gorszymi przedplonami od łubinu wąskolistnego. Na glebie lekkiej w rejonie i latach o relatywnie niskich sumach opadów w okresie wegetacji, niezależnie od przedplonu, nawożenie azotem powyżej 80 kg $N \cdot ha^{-1}$ nie zwiększało istotnie plonu ziarna, ale wpływało korzystnie na jego wartość technologiczną.

Słowa kluczowe: gluten, liczba opadania, łubin wąskolistny, masa hektolitra, rzepak jary, wskaźnik sedymentacji

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