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YIELD AND MALTING QUALITY OF SPRING BARLEY CULTIVAR PRESTIGE DEPENDING ON NITROGEN FERTILIZATION

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Abstract. The aim of this study was to precisely quantify the effect of different level and time of nitrogen application on the field and malting quality of spring barley grain of cultivar Prestige. Source of results was the field experiment carried out in 2003-2005. The experiment was carried out with the split-plot method in 4 replications. 8 fertilization combinations were tested (0; 20; 40; 40 (20 + 20); 60; 60 (40 + 20); 80; 80 (60 + 20) kg $N \cdot ha^{-1}$). It was found that in soil of the good wheat complex at content $N_{min.}$ = 55-77 $kg \cdot ha^{-1}$ in layer 0-90 cm in spring high grain yields are obtained already at fertilization 40-60 kg $N \cdot ha^{-1}$. Considerably higher productivity of these rates is obtained when they were divided into two parts – presowing and that applied at 23 BBCH stage. Raw material of the malting cultivar (Prestige) collected under different conditions of weather (year with average total precipitation and wet year) and fertilization (N rates from 20 to 80 kg $N \cdot ha^{-1}$) is characterized by small variability of main qualitative index values of grain, malt and wort and comprehensive Q index according to EBC.

Key words: β-glucans, grain filling, Kolbach index, malt, soluble protein, wort

INTRODUCTION

Nitrogen fertilization is a cultivation factor strongly differentiating the height of barley grain yield [Pecio 2002, Błażewicz and Liszewski 2003, Pecio and Bichoński 2003]. High N rates create favourable conditions for gaining high productivity per 1 ha, but may also cause a higher risk of plant lodging along with its negative results, both for the field and physical characters of grain [Pecio 2005]. Nitrogen is also strongly connected with malting grain quality, it can decrease 1000 grain weight and their filling as well as considerably increase the content of reserve proteins in grain, which results in a decrease in malt extractivity [Pecio 2002, Pecio and Bichoński 2003]. Applying high N rates may result in a high activity of α- and β-amylase, as well as an increase in diastatic power of malt [Pecio and Bichoński 2006].

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In the working hypothesis it was assumed that the grain yield of malting spring barley may be positively affected by high – even up to 80 kg – N rates. Their negative effect on malting quality can be lower under conditions of its application only before sowing than in the case of delay the application of a part of nitrogen rate at the initial tillering stage of plants.

The aim of this study was to precisely quantify the effect of different levels and times of application of nitrogen as a cultivation factor responsible for the yield and malting quality of spring barley grain.

MATERIAL AND METHODS

The experiment was established in 2003-2005, at the Production and Research Station in Bałcyny near Ostróda (53°35' N; 19°51' E) in a typical podsolic soil, formed from light loam, classified as the good wheat complex, soil quality class IIIa. In all the years of the study the topsoil was characterized by a slightly acid reaction, moderate abundance in available phosphorus and potassium, and a high proportion of magnesium. The experiment was carried out with the split-plot method in 4 replications, according to the scheme presented in Table 1.

Table 1. Level and time of nitrogen fertilization
Tabela 1. Poziom i termin nawożenia azotem

Combination Kombinacja	Nitrogen rate Dawka azotu $kg \cdot ha^{-1}$	Time of application – Termin stosowania	
		before sowing – przedsiewnie (BBCH 00)	tillering stage – faza krzewienia (23 BBCH)
a	control – kontrola	–	–
b	20	20	–
c	40	40	–
d	40	20	20
e	60	60	–
f	60	40	20
g	80	80	–
h	80	60	20

The forecrop was winter wheat, after which the standard tillage was performed. Before sowing spring barley fertilization with phosphorus and potassium was applied (P – 17.4 kg, K – 66.4 $kg \cdot ha^{-1}$), and the rates were determined according to soil abundance and the level of expected harvest. Mineral nitrogen content determined in spring in the soil layer 0-90-cm in 2003 was 77 kg, in 2004 – 55 kg, and in 2005 – 53 kg. Spring barley of the cultivar Prestige was always sown from 10th to 20th April, in the amount of 190-200 kg grain per 1 ha. The area of plots for harvesting was 15 m^2. Weed infestation was controlled at 25 BBCH stage using the mixture Granstar 75 WG (tribenuron-methyl) + Trend 90 EC (ethoxylated isodecyl alcohol). Seed dressing Oxafun T 75 WS (carboxin + tiuram) and spraying with the fungicide Alert 375 SC (flusilazole + carbendazim) at 33 BBCH stage was applied against fungal pathogens. One-phase harvest was made at the full maturity stage (89 BBCH).

The study involved the annual determination of grain yield (moisture 15%) and its yield structure components. Quality indices of raw material were measured in grain samples collected in 2003 and 2004, where were determined as follows: grain filling (drum grain sorter), germination energy after 72 h (PN-69/R-65950), total protein content in grain and the content of total and soluble protein in malt with the Kjeldahl method, Kolbach index (PN-A-79083-9), malt extractivity (PN-A-79083-6), apparent final attenuation and the flow time of wort (PN-A-79083-6), β-glucan content in wort (enzymatic method, EBC method 8.11.1.), wort viscosity (PN-A-79083-7), diastatic power (PN-A-79083-10) and the Q index referring to the comprehensive evaluation of malting quality [Klockiewicz-Kamińska 2005].

Results were statistically worked out using the analysis of variance at the significance level P = 0.05. Significance of differences between means was evaluated with the Duncan test [Elandt 1964]. In statistical analyses referring to qualitative characters of grain, malt and wort annual data obtained from each combination were treated as replications.

The system of thermal and moisture conditions in individual growing seasons was varied (Table 2). The first year (2003), according to the criterion adopted by Kaczorowska [1962], was average in respect of precipitation and warmer than the long-term period. Calculated hydrothermal Seljaninov coefficients in April and June, according to the classification by Skowera and Puła [2004], indicated a rather dry period, and for May and July – rather wet. Under such conditions spring barley gave the highest yields (Table 3). By contrast, the second year (2004) was wet (124% of the long-term total precipitation) and colder than the long-term period. Calculated effective precipitation indices in each month showed a noticeable excess of precipitation (quite wet, wet and very wet periods) in relation to the amount of water evaporated by plants, which ensured the yield on an average level. The third year (2005) was characterized by a slightly higher total precipitation than in the long-term period and the poorest water supply during spring barley growing season (only 78% of long-term total precipitation). Particularly unfavourable values of hydrothermal coefficient were recorded in April and June (the period of drought), and the obtained barley grain yield under such pluviothermal conditions was the lowest.

Table 2. The system of thermal and moisture conditions during the growing season of spring barley as recorded at the meteorological station Bałcyny
Tabela 2. Układ warunków termicznych i wilgotnościowych w okresie wegetacji jęczmienia jarego według notowań stacji meteorologicznej w Bałcynach

Research year Rok badań	Month – Miesiąc					Sum/Mean Suma/Średnia
	April kwiecień	May maj	June czerwiec	July lipiec	August sierpień	
Total temperature – Suma temperatury, °C						
2003	183.1	440.1	495.5	585.7	537.1	2 241.5
2004	233.0	341.3	435.6	502.4	564.3	2 076.6
2005	231.5	386.7	446.9	585.8	519.8	2 170.7
1961-2000	213.0	390.6	474.0	542.5	530.1	2 150.2
Total precipitation – Suma opadów, mm						
2003	23.6	78.6	60.7	118.2	34.9	316.0
2004	51.5	87.1	90.6	78.8	89.3	397.3
2005	22.0	68.2	35.4	83.9	39.6	249.1
1961-2000	33.3	61.1	69.5	82.5	74.9	321.3
Seljaninov coefficient – Współczynnik Seljaninova						
2003	1.29	1.79	1.23	2.02	0.65	1.41
2004	2.21	2.55	2.07	1.57	1.58	1.91
2005	0.95	1.76	0.79	1.43	0.76	1.15

Table 3. Grain yield of spring barley, Mg·ha^{-1}
Tabela 3. Plon ziarna jęczmienia jarego, Mg·ha^{-1}

Research year Rok badań	Level and time of nitrogen fertilization – Poziom i termin nawożenia azotem kg N·ha^{-1}								Mean Średnia
	control kontrola	20	40	40 (20 + 20)	60	60 (40 + 20)	80	80 (60 + 20)	
2003	7.85 c	8.11 b	8.62 a	8.49 ab	8.54 a	8.65 a	8.45 ab	8.55 a	8.41 a
2004	4.20 c	5.68 bc	6.21 b	6.71 b	6.54 b	7.38 a	7.41 a	7.58 a	6.47 b
2005	3.78 c	4.38 bc	5.34 ab	5.21 b	5.29 ab	6.06 a	6.12 a	6.40a	5.32 c
Mean Średnia	5.28 c	6.06 b	6.72 ab	6.80 ab	6.79 ab	7.37 a	7.33 a	7.52 a	–

a, b, c – homogeneous groups (P = 0.05) – grupy jednorodne (P = 0,05)

RESULTS AND DISCUSSION

Grain yield, its structure components

Spring barley grown in the soil of good wheat complex was characterized with a high grain productivity (Table 3). In the control combinations (without nitrogen) grain yield ranged from 3.78 to 7.85 Mg·ha^{-1}, and in those fertilized with nitrogen from 4.38 to 8.65 Mg·ha^{-1}.

From calculated correlation coefficients it follows that a higher relationship between the level of nitrogen fertilization and grain yield occurs in the case where its rates were divided into two parts and the other one was applied at the tillering stage (23 BBCH) (Fig. 1). Increasing nitrogen by1 kg in divided rates resulted in an increase in grain yield by 0.029 Mg·ha^{-1}, and in not divided rates by 0.024 Mg·ha^{-1}.

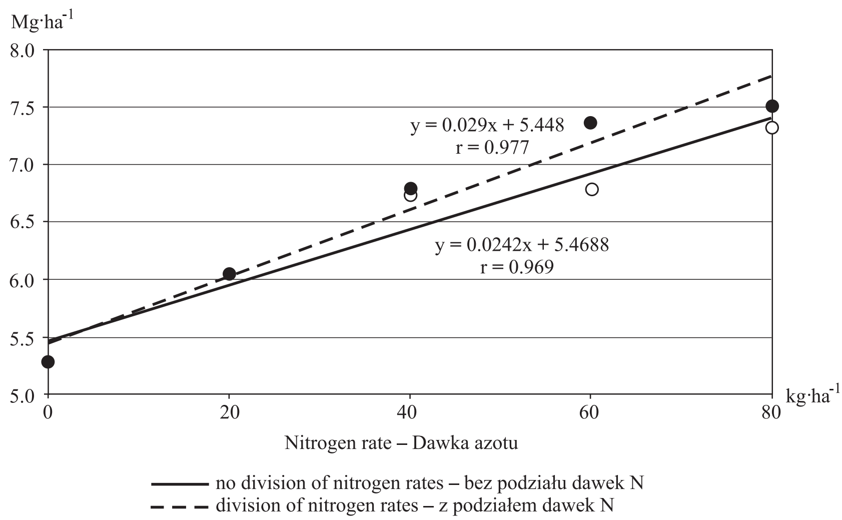

Fig. 1. Yields of spring barley cultivar Prestige depending on the level and time of nitrogen fertilization (average of 3 years)
Rys. 1. Plonowanie jęczmienia jarego odmiany Prestige w zależności od poziomu i terminu nawożenia azotem (średnio z 3 lat)

In the first year of the study, with an average total precipitation, at the highest content of mineral N in soil, the grain yield increased only up to a rate of 40 kg N. In the second year (wet), as well as in the third (dry) – the yield increased up to the level N-60, applied in two parts: 40 kg before sowing + 20 kg at 23 BBCH stage (Table 3).

Nitrogen fertilization at the applied rates (20-80 kg N) resulted in a successive increase in density of productive ears in the stand up to a level of 80 kg N applied at a single rate before sowing (Table 4). This was the main element differentiating grain yield per the area unit. In contrast, variability in the number of grains in ear and 1000 grain weight as affected by N fertilization was insignificant (Table 4). Also in the study by Liszewski *et al*. [2011] and Pecio and Bichoński [2006] a significant increase in the grain yield of brewing barley was observed on treatments fertilized with a rate of 40-60 kg N·ha^{-1}, mostly as a result of forming a larger number of productive ears per the area unit. This is also confirmed by results of studies by other authors [Koziara *et al*. 1998, Błażewicz and Liszewski 2003].

Table 4. Yield components (mean of 3 years)
Tabela 4. Elementy struktury plonu (średnia z 3 lat)

Specification Wyszczególnienie	Level and time of nitrogen fertilization – Poziom i termin nawożenia azotem kg N·ha^{-1}							
	control kontrola	20	40	40 (20 + 20)	60	60 (40 + 20)	80	80 (60 + 20)
Liczba kłosów, szt.·m^{-2} Number of ears·m^{-2}	480 c	512 bc	552 b	560 ab	559 ab	578 ab	656 a	613 a
Liczba ziarn w kłosie, szt. Number of grains per ear	19.1	18.9	19.4	20.0	20.4	21.6	19.9	20.7
Masa 1000 ziaren, g Weight of 1000 grains	52.1	52.3	52.9	53.3	54.3	52.0	52.4	52.3

a, b, c – homogeneous grups (P = 0.05) – grupy jednorodne (P = 0,05)

Technological quality

Grain filling determined on sieves of 2.5 mm in diameter was very high (99.1%) and uniform – even at the highest fertilization (80 kg N·ha^{-1}), but differences between fertilization combinations did not exceed 1% and were not statistically significant (Table 5). Rozbicki [1994] reports that the grain filling of brewing barley should not be lower than 90%. Such uniform grain equally absorbs water during soaking, germinates evenly and consequently, it gains a desirable degree of malt modification. According to Kunze [1999] only the grain fraction of more than 2.5 mm is suitable for malt production, whereas smaller values of this parameter are treated in the malt-house as offal which only can be used as fodder. In the experiment of Błażewicz and Liszewski [2003] the most favourable grain filling was obtained using 25 or 50 kg N·ha^{-1}, at a single rate, and higher levels of N fertilization caused a decrease in the numerical value of this character. In the study by Pecio and Bichoński [2002, 2006] significant reduction in grain size was observed along with an increase of nitrogen rate.

Grain germination energy was on average 97.1% and it did not depend significantly on the level and time of nitrogen fertilization (Table 5). Applied nitrogen rates, even those highest, did not lower its value in relation to the control treatment without nitrogen. According to Kunce [1999], the good quality raw material for malt production should be characterized by at least 95% germination energy. Grain which germinates slowly or does not germinate at all is usually subjected to decay processes and makes a good substrate for development of bacteria and moulds, which is the source of malt infection [Baca *et al*. 1998].

Table 5. Indices of malting quality of grain
Tabela 5. Wyróżniki jakości browarnej ziarna

Research year Rok badań	Level and time of nitrogen fertilization – Poziom i termin nawożenia azotem kg N·ha^{-1}								Mean Średnia
	control kontrola	20	40	40 (20 + 20)	60	60 (40 + 20)	80	80 (60 + 20)	
Grain filling – Celność ziarna, %									
1	98.6	98.6	99.4	99.4	99.4	99.3	99.1	99.2	99.1
2	99.2	98.9	98.9	98.9	99.1	99.0	98.9	98.9	99.0
Mean Średnia	98.9	98.8	99.2	99.2	99.3	99.2	99.0	99.1	99.1
non-significant differences – różnice nieistotne									
Germination energy – Energia kiełkowania, %									
1	98.0	98.5	99.2	98.9	99.0	98.7	97.6	98.3	98.5
2	94.8	94.2	96.4	95.6	95.4	97.0	95.6	95.8	95.6
Mean Średnia	96.4	96.4	97.8	97.3	97.2	97.9	96.6	97.1	97.1
non-significant differences – różnice nieistotne									
Total protein in grain, % d.m. – Białko ogółem w ziarnie, % s.s.									
1	11.2	11.1	11.5	11.6	11.7	11.9	11.8	10.1	11.4
2	10.6	10.1	9.8	9.8	9.5	9.6	9.6	9.7	9.8
Mean Średnia	10.9	10.6	10.7	10.7	10.6	10.8	10.7	10.8	10.6
non-significant differences – różnice nieistotne									

Grain from all the combinations (also those fertilized at the level N-80) was characterized by a relatively low content of protein (Table 5), which made it useful for malting purposes [Kunze 1999, Klockiewicz-Kamińska 2005]. Along with increasing rates of nitrogen fertilizers from 20 to 80 kg N·ha^{-1} no significant differences were observed in content of this component in grain. It may be concluded that the very high yield affected the so-called good dilution of total protein. In the studies by Pecio and Bichoński [2003, 2006] protein content in grain increased significantly already after exceeding a rate of 60 kg N, and favourable contents of this component, staying within the standard expected for brewing barley, were obtained at fertilizing with rates of 20 and 40 kg N·ha^{-1}. Michałowska [2004] reports that an amount of protein above 11.5% in raw material leads to formation of cloudiness, and decreasing its value below 9% of dry matter results in worsening of beer foam quality.

Varied rates of nitrogen only to a small extent affected malt productivity. Under conditions of growing fertilization level, only a tendency to lower the efficiency of malting process could be observed. Decreasing malt productivity under the influence of growing nitrogen rates was also obtained in the study by Błażewicz *et al*. [2011]. Also no significant effect of the tested fertilizing combinations on the content of total protein and protein soluble in malt was observed in the present study (Table 6).

Kolbach index, which is used to express the proteolytic modification of protein in malt, from almost all the tested combinations (except for those fertilized with single rates of 60 and 80 kg N·ha^{-1}) met standard requirements (Table 6), which according to Molina-Cano [1987] should stay within the range from 36.3 to 43.8%. Too high protein modification is not recommended, as obtained beer is characterized by weak foam and unsatisfactory slight bitterness [Moll 1991]. The study of Pecio [2002], as well as Pecio and Bichoński [2006] prove that an increase in nitrogen rate from 20 to 60 kg N·ha^{-1} favourably decreased Kolbach index.

Table 6. Indices of malting quality of malt
Tabela 6. Wyróżniki jakości browarnej słodu

Research year Rok badań	Level and time of nitrogen fertilization – Poziom i termin nawożenia azotem kg N·ha^{-1}								Mean Średnia
	control kontrola	20	40	40 (20 + 20)	60	60 (40 + 20)	80	80 (60 + 20)	
Malt yield, % d.m. – Wydajność słodu, % s.s.									
2003	83.4	84.2	82.4	82.5	82.6	84.9	82.9	78.2	82.6
2004	89.3	88.5	88.8	89.5	89.5	88.2	89.0	88.4	88.9
Mean Średnia	86.4	86.4	85.6	86.0	86.1	86.5	86.0	83.3	85.8
non-significant differences – różnice nieistotne									
Total protein in malt, % d.m. – Białko ogółem w słodzie, % s.s.									
2003	10.9	11.0	11.0	10.8	11.0	11.2	11.3	11.2	11.1
2004	9.4	9.3	9.0	9.0	8.6	8.6	8.8	8.9	9.0
Mean Średnia	10.2	10.2	10.0	9.9	9.8	9.9	10.1	10.0	10.1
non-significant differences – różnice nieistotne									
Soluble protein in malt, % d.m. – Białko rozpuszczalne w słodzie, % s.s.									
2003	4.4	4.7	4.4	4.7	4.8	4.6	4.9	4.6	4.6
2004	4.4	4.4	4.2	4.2	4.2	4.2	4.2	4.1	4.2
Mean Średnia	4.4	4.6	4.3	4.5	4.5	4.4	4.6	4.4	4.4
non-significant differences – różnice nieistotne									
Kolbach index – Liczba Kolbacha, %									
2003	40.0	42.8	40.1	43.1	43.2	41.3	43.4	41.1	41.9
2004	47.2	46.9	46.3	46.1	48.9	48.4	47.6	46.4	47.2
Mean Średnia	43.6	44.9	43.2	44.6	46.1	44.8	45.5	43.8	44.6
non-significant differences – różnice nieistotne									
Malt extractivity, % d.m. – Ekstraktywność słodu, % s.s.									
2003	82.7	82.6	82.3	82.6	82.2	82.1	81.8	81.9	82.3
2004	83.4	84.0	83.6	83.8	83.9	84.0	83.8	84.0	83.8
Mean Średnia	83.1	83.3	83.0	83.2	83.1	83.1	82.8	83.0	83.1
non-significant differences – różnice nieistotne									

Malt extractivity should be evaluated as high (on average 83.1%) and not significantly varied by the level and time of nitrogen applied in fertilizers (Table 6). In the study by Pecio and Bichoński [2002, 2006] an increase in nitrogen fertilization caused a significant fall in malt extractivity. Extractivity is the main economic index and therefore it is the basis for barley usefulness for brewery malt production [Molina-

-Cano 1987]. Malt of good quality should be characterized by extractivity not less than 79.5% [Kunze 1999]. As much as 45% points of malting quality of grain is attributed to this parameter [Molina-Cano 1987].

It is notable that the content of β-glucans in wort was higher in 2003, with an average soil moisture, than in grain collected in 2004 characterizing by heavy rainfalls (Table 7).

Table 7. Indices of malting quality of wort
Tabela 7. Wyróżniki jakości browarnej brzeczki

Research year Rok badań	Level and time of nitrogen fertilization – Poziom i termin nawożenia azotem kg N·ha^{-1}								Mean Średnia
	control kontrola	20	40	40 (20 + 20)	60	60 (40 + 20)	80	80 (60 + 20)	
β-glucan content – Zawartość β-glukanów, mg·l^{-1}									
2003	224.0	223.0	254.0	224.0	239.0	240.0	257.0	250.0	238.9
2004	159.0	141.0	122.0	151.0	123.0	166.0	192.0	193.0	155.9
Mean Średnia	191.5	182.0	188.0	187.5	181.0	203.0	224.5	221.5	197.4
non-significant differences – różnice nieistotne									
Wort viscosity – Lepkość brzeczki, mPa.s.									
2003	1.50	1.50	1.50	1.51	1.52	1.52	1.51	1.51	1.51
2004	1.47	1.46	1.46	1.47	1.45	1.46	1.47	1.46	1.46
Mean Średnia	1.49	1.48	1.48	1.49	1.49	1.49	1.49	1.49	1.49
non-significant differences – różnice nieistotne									
Flow time – Czas spływu, min.									
2003	55.0	50.0	50.0	85.0	45.0	70.0	65.0	50.0	58.8
2004	60.0	60.0	95.0	95.0	75.0	95.0	80.0	70.0	78.8
Mean Średnia	57.5	55.0	72.5	90.0	60.0	82.5	72.5	60.0	68.8
non-significant differences – różnice nieistotne									
Apparent final attenuation – Stopień ostatecznego odfermentowania, %									
2003	82.9	82.8	82.7	82.6	82.6	82.8	82.5	82.7	82.7
2004	83.7	84.1	84.3	84.3	84.6	84.1	84.1	84.5	84.2
Mean Średnia	83.3	83.5	83.5	83.5	83.6	84.1	83.5	83.6	83.5
non-significant differences – różnice nieistotne									
Diastatic Power, u.W-K – Siła diastatyczna, j.W-K									
2003	430.0	420.0	450.0	460.0	440.0	460.0	430.0	450.0	442.5
2004	400.0	410.0	410.0	400.0	410.0	410.0	350.0	400.0	398.8
Mean Średnia	415.0	415.0	430.0	430.0	425.0	435.0	390.0	425.0	420.7
non-significant differences – różnice nieistotne									

In the wet year (2004) low fertilization (20-40 N) caused even a decrease in the content of β-glucans, and fertilization at a level of 60 (40 + 20) and 80 kg N – resulted in an increase in the numerical value of this character by about 13%. In the year with an average total precipitation (2003) malt from barley obtained from the control without N gave wort less abundant in β-glucans by about 7% than that fertilized with nitrogen.

Unfavourable effect of large nitrogen rates on the content of β-glucans in wort was observed in the study by Bichoński *et al*. [2003], Noworolnik [1998) and Pecio and Bichoński [2006]. The earlier study by Moll [1991] indicates that the content of β-glucans higher than 250 $mg \cdot l^{-1}$ hinders filtration of wort and beer, which from the point of view of modern production technology is a very undesirable phenomenon. Varietal experiments carried out by Michałowska [2003] confirmed that apart from the genetic factor, the climatic and moisture conditions are the most important factor affecting the content of β-glucans in barley.

Viscosity, which is the index determining the filtration and clarity of wort, stayed at favourably low level and was on average 1.49 mPa.s. (Table 7). Fertilization did not differentiate significantly the numerical value of this character. According to Pecio and Bichoński [2006], nitrogen fertilization favours an increase in wort viscosity. Kunze [1999] reports that viscosity should stay within the range 1.51-1.63 mPa.s. and it depends on the content of β-glucans. Additionally, this index also indicates a degree of modification of starch malt, which is caused by the activity of cyto- and amylolytic enzymes during malting and mash.

Nitrogen fertilization did not differentiate the flow time of wort (Table 7). From the data presented it follows that the shortest time of wort filtration (statistically insignificant), needed for complete filtering of mash, lasting 55 minutes, was recorded on the treatment fertilized with a rate of 20 kg $N \cdot ha^{-1}$. Applied high levels of nitrogen fertilization caused only a tendency to slow down this process.

A degree of final defermentation and diastatic power did not show significant differences under the influence of level and time of nitrogen fertilization (Table 7). Not proved statistically, the highest values of tested characters were obtained in the combination fertilized with a rate of 60 kg $N \cdot ha^{-1}$, where nitrogen was applied at two times. Both lower and higher nitrogen rates applied in the study did not have a significant effect on the values of tested parameters. Similar results were obtained in the earlier studies [Błażewicz and Liszewski 2003, Pecio and Bichoński 2006].

The summary evaluation of the malting quality of spring barley grain of the cultivar Prestige indicates that the raw material obtained, irrespective of the applied fertilization combinations, always represented the brewery type (Table 8). Under the harvest conditions of 2003 (average in respect of precipitation) grain was classified as good category, and in 2004 (wet year) to the good-very good category. Raw material of better quality (statistically insignificant) was obtained when nitrogen fertilization stayed within the range 20-40 kg $N \cdot ha^{-1}$ and was applied only before sowing. Dividing nitrogen rates into two parts (before sowing and at the tillering stage) caused tendencies to have a more favourable effect on the comprehensive malting index evaluation only for 60 and 80 kg $N \cdot ha^{-1}$. Baca *et al*. [1998] claim that the quality of brewing barley grain is determined mainly by soil and weather conditions, and particularly moisture, insolation and the temperature during maturing and harvest. Prolonged droughts in those periods are unfavourable, and excessive moisture even worse. Raw material obtained in such conditions is usually characterized by a decreased germination energy of grain. Larger β-glucan content in wort and higher proportion of overgrown and moulded grains.

Table 8. Malting quality index Q
Tabela 8. Kompleksowa ocena browarna – wskaźnik Q

Research year Rok badań	Level and time of nitrogen fertilization – Poziom i termin nawożenia azotem kg N·ha^{-1}								Mean Średnia
	control kontrola	20	40	40 (20 + 20)	60	60 (40 + 20)	80	80 (60 + 20)	
2003	5.65	5.95	6.45	5.90	5.25	5.10	5.00	4.85	5.52
2004	7.50	8.30	7.90	7.90	7.90	8.30	7.75	8.30	7.98
Mean Średnia	6.58	7.13	7.18	6.85	6.58	6.70	6.38	6.58	6.75

non-significant differences – różnice nieistotne

CONCLUSIONS

1. In soil of the good wheat complex at the content of $N_{min.}$ = 55-77 kg·ha^{-1} in the layer 0-90 cm in spring high grain yields are obtained already at 40-60 kg N·ha^{-1}. Considerably higher productivity of those rates can be achieved by their division into two parts – presowing and at 23 BBCH stage.

2. Raw material of the malting cultivar (Prestige) collected under different natural conditions (the year with an average total precipitation and the wet year) and fertilization (N rates from 20 to 80 kg N·ha^{-1}) is characterized by a low variability of values of the main quality indexes of grain, malt and wort and comprehensive Q index according to EBC.

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NAWOŻENIE AZOTEM A PLON I JAKOŚĆ BROWARNA JĘCZMIENIA JAREGO ODMIANY PRESTIGE

Streszczenie. Celem badań było szczegółowe skwantyfikowanie wpływu zróżnicowanego poziomu i terminu aplikacji azotu na plon i wartość browarną ziarna jęczmienia jarego odmiany Prestige. Źródłem wyników był eksperyment polowy przeprowadzony w latach 2003-2005. W doświadczeniu prowadzonym metodą split-plot, w 4 replikacjach, testowano 8 kombinacji nawozowych (0; 20; 40; 40 (20 + 20); 60; 60 (40 + 20); 80; 80 (60 + 20) kg $N \cdot ha^{-1}$). Stwierdzono, że na glebie kompleksu pszennego dobrego przy zawartości $N_{min.}$ = 55-77 $kg \cdot ha^{-1}$ w warstwie 0-90 cm wiosną uzyskuje się wysokie plony ziarna już przy nawożeniu 40-60 kg $N \cdot ha^{-1}$. Wyraźnie większą produkcyjność tych dawek osiąga się w przypadku ich podziału na dwie części – przedsiewną oraz zastosowaną w stadium 23 BBCH. Surowiec odmiany browarnej (Prestige) zebrany w różnych warunkach przyrodniczych (rok o przeciętnej sumie opadów i rok wilgotny) i nawozowych (dawki N od 20 do 80 kg $N \cdot ha^{-1}$) charakteryzuje się małym zróżnicowaniem wartości głównych wskaźników jakościowych ziarna, słodu i brzeczki oraz kompleksowym wskaźnikiem Q według EBC.

Słowa kluczowe: β-glukany, białko rozpuszczalne, brzeczka, celność ziarna, liczba Kolbacha, słód

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