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FOLIAR NITROGEN FERTILISATION AS A FACTOR DETERMINING TECHNOLOGICAL PARAMETERS OF WINTER WHEAT

DOLISTNE NAWOŻENIE AZOTEM JAKO CZYNNIK KSZTAŁTUJĄCY PARAMETRY TECHNOLOGICZNE PSZENICY OZIMEJ

Abstract: Over 2002–2005 at the Experiment Station of the Agricultural University in Nitra, at Sladkovicovo – Novy Dvor, about 30 km away from Nitra (Slovakia) a field experiment was carried out which aimed at defining the effect of different nitrogen fertiliser doses and its application method on the value of selected technological parameters in 'Petrana' winter wheat grain and flour. In the present research a varied nitrogen fertilisation applying the entire dose range resulted in an increase in the content of total protein in 'Petrana' winter wheat grain. However, a significant increase in the value of that character was recorded after the application of 80 kg N $\cdot$ ha^{-1}, as compared with the control and the treatment with 50 kg N $\cdot$ ha^{-1}. A varied nitrogen fertilisation, applying the entire dose range, enhanced the values of the technological parameters studies. However, the nitrogen dose optimal for the key indicators of the baking value of flour, namely the sedimentation index value and bread volume have been defined as 95 kg $\cdot$ ha^{-1} and the content of wet gluten and flour water holding capacity – 80 kg $\cdot$ ha^{-1}.

Keywords: winter wheat, nitrogen fertilisation, technological parameters

The most essential factors which affect wheat yielding and grain quality include mineral fertilisation, especially nitrogen fertilisation [1–10]. It increases the content of total protein in grain and the amount of fractions determining the quantity and quality of gluten which, in turn, has a great effect on the wheat baking parameters. And thus for respective new cultivars, it is indispensable to investigate their reaction to the amount of nitrogen doses, expressed not only in a form of grain yield but also the values of characters defining its quality. Besides the amount of fertiliser doses, similarly the

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application method is of considerable importance since the supply of nitrogen to plants should closely harmonize with their development stages. Over the recent years, more and more often the technology of foliar nitrogen application in a fluid form in wheat has been applied [11–13]. Such a method of applying nitrogen is aimed to increase the effectiveness of fertilisation and to maintain a good quality of the yield.

According to Mazurek and Sulek [14], the yield-forming effect of nitrogen fertilisation depends considerably on the method of fertilisation with this nutrient, however, there is little coverage on the relationship between the application technique and grain quality characters and, as a result, flour.

With that in mind, over 2002–2005 a field experiment was carried out on a medium heavy degraded chernozem the aim of which was to determine the effect of different nitrogen fertiliser doses and its application method on the values of selected technological parameters in 'Petrana' winter wheat grain and flour.

Materials and methods

A field experiment was carried out over 2002–2005 at the Experiment Station of the Agricultural University in Nitra, at Sladkovicovo – Novy dvor (17°34′40″ east longitude and 48°22′20″ west latitude), about 30 km away from Nitra (Slovakia). The research involved 'Petrana' winter wheat grain sown in the amount of 5 m grains · ha^{-1}, exposed to varied nitrogen fertilisation (Dusadam fertiliser – 26 %N). The present research was based on a single-factor field experiment, set up following the randomised blocks method in four replications. The soil (chernozem) reaction was neutral (pH in KCl 6.6). The soil showed mean mineral nitrogen content (N_{min} = 14.0 mg · kg^{-1} soil), mean content of available phosphorus (P = 65.7 mg · kg^{-1} soil), a high content of available potassium (K = 247 mg · kg^{-1} soil), very high content of available calcium (Ca = 331 mg · kg^{-1} soil) and the content of humus of 2.95 %. The plots 10 m^2 (8 × 1.25 m) in size were fertilised with four nitrogen doses: the control without nitrogen (N_0); 50 kg N · ha^{-1} (N_{50}) was applied once at the start of the spring vegetation (into soil); 80 kg N · ha^{-1} (N_{80}) was split: 50 kg N · ha^{-1} was applied at the start of spring vegetation (into soil) and 30 kg N · ha^{-1} was applied at the beginning of the shooting phase (foliar application); 95 kg N · ha^{-1} (N_{95}) was split: 50 kg N · ha^{-1} was applied at the start of spring vegetation (into soil), 30 kg N · ha^{-1} – at the beginning of the shooting phase (foliar application) and 15 kg N · ha^{-1} – after tillering and prior to flowering (foliar application). Spring wheat constituted the forecrop. Tillage, winter wheat sowing and harvest were performed compliant with the agrotechnical requirements optimal for the species. During the experiment, pesticides were used by spraying against viral diseases (prevention treatment: Naztak 10EC at the dose of 0.15 dm^3 · ha^{-1}) and against weeds (Granstar WG75 at the dose of 20 g · ha^{-1}).

In the adequately prepared plant material, the following baking value indices were determined: the falling number (according to Hagberg, PN-ISO-3093) [15], content of total protein (%N · 5.7, PN-75A-04018) [16], content of gluten (PN-A-74-043) [17], sedimentation index value (the Zeleny test, PN-ISO-5529) [18], flour water holding capacity (PN-ISO 5530) [19] as well as bread volume obtained from 100 g of flour (PN-A-74108) [20].

The present research results were statistically verified with the analysis of variance and the boundary differences were estimated using the Tukey test at the significance level of p = 0.05. To define the compounds and relationships between the nitrogen fertilisation applied and the values of the spring wheat quality characters investigated, the results were verified with the analysis of simple correlation.

Weather conditions throughout the experiment (2002–2005 growing seasons) are given in Table 1. Over the 2002/2003 and 2003/2004 growing seasons the mean air temperature were higher and total rainfall lower as compared with many-year means by 0.5 °C and 0.2 °C as well as 111.0 mm and 61.7 mm (which accounted for 19.8 % and 9.0 %), respectively. The last experiment year, on the other hand, showed the mean air temperature at the same level as the many-year value, whereas the total rainfall slightly exceeded the mean for years (by 4.2 mm).

Table 1

Weather conditions in the vegetation seasons of 2002–2005

Month	2002/2003		2003/2004		2004/2005		Mean for 30 years	
	Temperature [°C]	Rainfall [mm]	Temperature [°C]	Rainfall [mm]	Temperature [°C]	Rainfall [mm]	Temperature [°C]	Rainfall [mm]
IX	14.9	62.1	15.8	16.0	14.7	35.4	15.4	37.0
X	9.7	78.2	7.9	66.0	11.7	45.3	10.1	41.0
XI	8.0	42.0	7.0	33.0	5.5	45.7	4.9	54.0
XII	–0.5	37.7	0.9	24.0	0.8	26.8	0.5	43.0
I	–1.9	33.0	–3.1	55.9	–0.1	31.0	–1.7	31.0
II	–1.8	0.7	1.6	31.1	–2.7	53.0	0.5	32.0
III	5.1	2.3	4.7	52.8	2.7	3.4	4.7	33.0
IV	10.7	27.0	11.7	36.3	11.0	78.7	10.1	43.0
V	18.8	44.5	14.3	36.9	15.2	60.9	14.8	55.0
VI	21.3	6.5	17.9	93.8	18.0	31.5	18.3	70.0
VII	21.2	92.0	20.0	33.8	20.5	59.0	19.3	64.0
VIII	22.7	24.0	20.1	19.4	19.1	94.5	19.2	58.0
Mean; Total	10.2	450.0	9.9	499.3	9.7	565.2	9.7	561.0

Results and discussion

The winter wheat yield is determined by a number of agrotechnical factors, most importantly nitrogen fertilisation, which coincides with the domestic and international literature reports [2, 5, 6, 21, 22]. The 'Petrana' winter wheat grain yield ranged from 6.68 to 7.59 $Mg \cdot ha^{-1}$; an average of 7.21 $Mg \cdot ha^{-1}$.

The falling number is a quality parameter one should start the evaluation of the baking value of grain from since the present results above the norm, namely, 175–200 s (mean activity of α-amylase) can suggest that the present material does not meet the consumption requirements. Sulek et al [12] claim that the falling number value is cultivar-specific and thus it depends on the genotype. The winter wheat grain studied demonstrated the value of the falling number of an average of 345 s (Fig. 1A), which suggests that it can be considered, compliant with the COBORU classification [23], to fall into the group of bread cultivars. The minimum value for that group is 200 s.

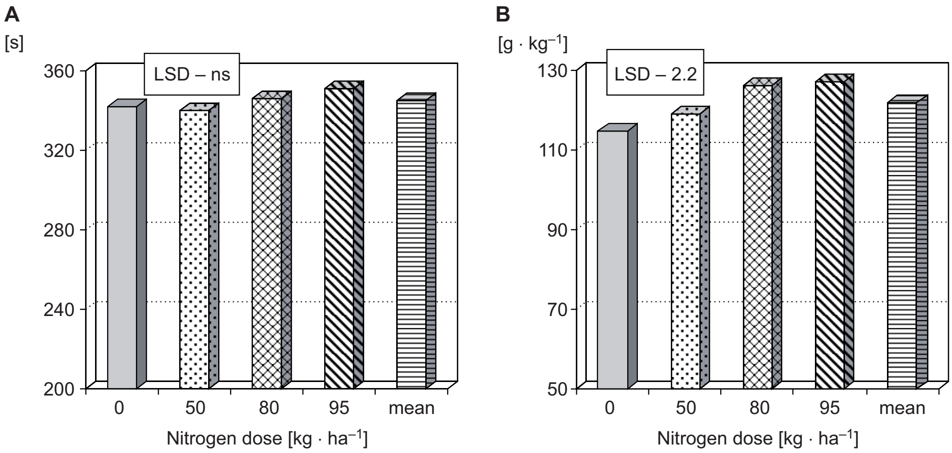

Fig. 1. Mean values of the falling number (A) and the content of total protein (B) in winter wheat grain depending on the nitrogen dose

The present research, similarly as the reports by Budzynski et al [1], Dubis and Borysewicz [2] and Podolska et al [8] showed no significant relationship between the nitrogen dose and the activity of α-amylase, while Knapowski and Ralcewicz [4] indicate that increasing the nitrogen doses under winter wheat to 120 kg $\cdot$ ha^{-1} resulted in a significant increase in the value of the falling number. High nitrogen doses, delaying the vegetation, can thus increase the falling number in the grain of some cultivars [24], and in others – decrease the falling number value [8].

Evaluating baking properties in wheat, much attention is paid to the amount of total protein which is essential not only due to its effect on the nutritious value but also due to the technological properties. The favourable effect of increasing nitrogen fertilisation doses on the content of total protein in wheat grain, in general, coincides with literature reports [1–6, 21, 23, 25] which show that intensifying fertilisation with this nutrient increases the protein content, most often, linearly. In the present research the nitrogen fertilisation level, unlike reported by Lozek and Spychaj-Fabisiak [22], resulted in significant changes in the content of total protein in 'Petrana' winter wheat grain (Fig. 1B). The highest value was noted when nitrogen was applied at the dose of 80 kg $\cdot$ ha^{-1}, when its second part (30 kg) was supplied in a form of foliar fertiliser at the shooting phase, and it was significantly higher than the content of protein in grain from the control and following the application of 50 kg N $\cdot$ ha^{-1}, respectively, by 8.7 % and 5.6 %.

Further increasing of the nitrogen fertilisation dose by 15 kg resulted in an increase in the protein content, however, it was non-significant. Sztuder and Swierczewska [13] report on foliar fertilisers increasing the content of total protein in grain, while Sulek et al [11, 12] demonstrated no significant differences in the content as affected by different nitrogen application methods.

Reports by Budzynski et al [1], Ducsay and Lozek [15] as well as by Lozek and Spychaj-Fabisiak [22] show that winter wheat, irrespective of the nitrogen fertilisation, demonstrated an average content of wet gluten, respectively, of 23.8 %, 28.5 % and 26.5 %. In the present research, the analysis of variance showed that the average content of wet gluten in 'Petrana' winter wheat grain accounted for 29.6 % (Fig. 2A). As reported by Stankowski et al [10], the average value of that character was higher and, depending on the cultivar, ranged from 39.5 % to 42.0 %, while Knapowski and Ralcewicz [3, 5], investigating 'Begra', 'Zyta' and 'Mikon' recorded mean gluten contents: 26.3 %, 30.9 % and 27.5 %, respectively.

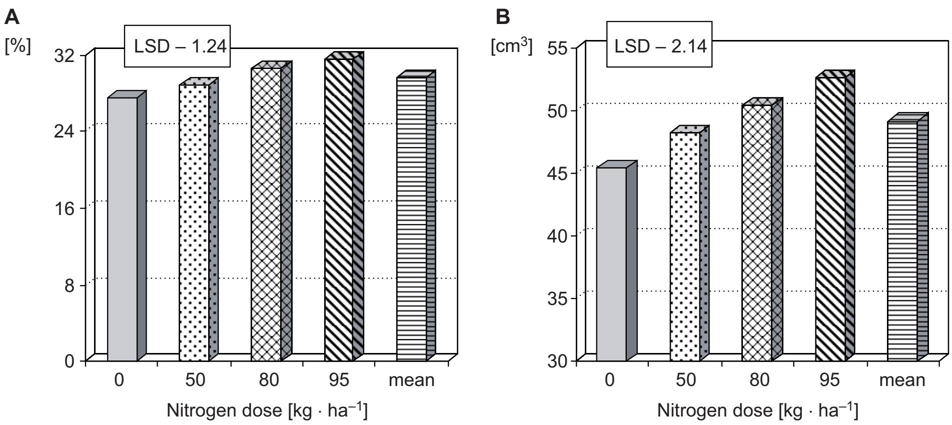

Fig. 2. Mean contents of wet gluten (A) and the values of the sedimentation test (B) in winter wheat grain depending on the nitrogen dose

The higher the nitrogen doses, the higher the content of wet gluten, which is reported by numerous authors [4–9, 10, 21, 22] investigating wheat. As noted by Knapowski and Ralcewicz [3], on average significantly highest amount of wet gluten in wheat grain was recorded after the application of 160 kg N $\cdot$ ha^{-1} (80 + 40 + 40) and it was higher as compared with treatments N_0, N_{80} and $N_{120,}$ by 14.7 %, 9.6 % and 4.7 %, respectively. Budzynski et al [1], on the other hand, investigating winter wheat cultivars, noted the highest significant value of the parameter by applying 180 kg N $\cdot$ ha^{-1}. Sztuder and Swierczewska [13] demonstrated that a clear increase in the amount of wet gluten in grain was due to the application of foliar fertilisers. A combined foliar fertilisation (urea + magnesium sulphate + Polvit Z/J) resulted in a 6.7 % higher content of the parameter, as compared with the control. In the present experiment 'Petrana' winter wheat reacted with a favourable increase in the content of wet gluten to each increase in the nitrogen dose (Fig. 2A), which also coincides with the significantly positive coefficient of simple correlation (r = 0.94) (Table 2). However, one shall assume 80 kg N · ha^{-1} (the other part of the dose – 30 kg as foliar fertiliser at the shooting phase) as the optimal dose. The value recorded for this treatment was significantly higher, as compared with the content of gluten for treatments N_0 and $N_{50,}$ respectively, by 3.1 % and 1.9 %. Sulek et al [11] report on a favourable effect on the value of the above given parameter being attributed to splitting of the nitrogen dose into three parts (the second and the third dose part at the shooting phase and tillering in a fluid form), while Mazurek and Sulek [14] claim that the nitrogen application method does not have a significant effect on the content of gluten.

Table 2

Significant coefficients of simple correlation between the winter wheat characters studied

Parameter		N fertilisation	1	2	3	4	5
Falling number	(1)	ns	—	ns	ns	–0.61	ns
Protein content	(2)	ns	ns	—	ns	ns	ns
Gluten content	(3)	0.94	ns	ns	—	ns	0.94
Sedimentation value	(4)	ns	–0.61	ns	ns	—	ns
Flour water holding capacity	(5)	0.96	ns	ns	0.94	ns	—
Bread volume	(6)	0.84	ns	ns	0.91	0.78	0.81

The analysis of simple correlation identified a close relationship between the content of wet gluten with flour water holding capacity (r = 0.94) and bread volume (r = 0.91) (Table 2). Knapowski and Ralcewicz [3, 5] showed positive relationships between the parameter and the falling number, content of protein, sedimentation index and the bread volume.

On average for the research years a varied nitrogen fertilisation modified the sedimentation index value (Fig. 2B). The higher the nitrogen fertilisation dose, the higher the value of the sedimentation test in flour obtained from winter wheat grain, similarly as in the experiments reported by other authors [1, 2, 4–6, 8]. Its highest (52.7 cm^3) significant value was noted as a result of the nitrogen application of 95 kg · ha^{-1} (50 + 30 + 15) and it was higher than the value for the control, following the application of 50 kg N · ha^{-1} and 80 kg N · ha^{-1} (50 + 30), respectively, by 13.8 %, 8.5 % and 4.4 %. Knapowski and Ralcewicz [4] report on 80 kg N · ha^{-1} to be significant for the sedimentation index value; they demonstrate a positive effect of fertilisation on that character up to 160 kg N · ha^{-1}. Budzynski et al [1], Dubis and Borysewicz [2] as well as Podolska et al [8], on the other hand, identified a favourable effect on the value of that quality character produced by applying nitrogen fertiliser up to, respectively, 150 kg · ha^{-1}, 180 kg · ha^{-1} and 200 kg · ha^{-1}, while Stankowski et al [10] and Spychaj-Fabisiak et al [25] showed that the value of the sedimentation number was not determined by nitrogen fertilisation.

As reported by Budzynski et al [1], flour from the grain of the winter wheat cultivars researched showed a good water holding capacity and accounted for 57.5 %. In the present experiment, in ‘Petrana’ an average value of flour water holding capacity accounted for 58.8 % (Fig. 3A). One shall also note that as for the value of that parameter, based on the classification reported by Podolska and Sulek [23], this cultivar can be considered to represent the elite wheat class (E). Higher mean values of the parameter, as compared with those reported in the present research, were recorded by Podolska et al [8], Stankowski et al [10] and Sulek et al [11] investigating wheat.

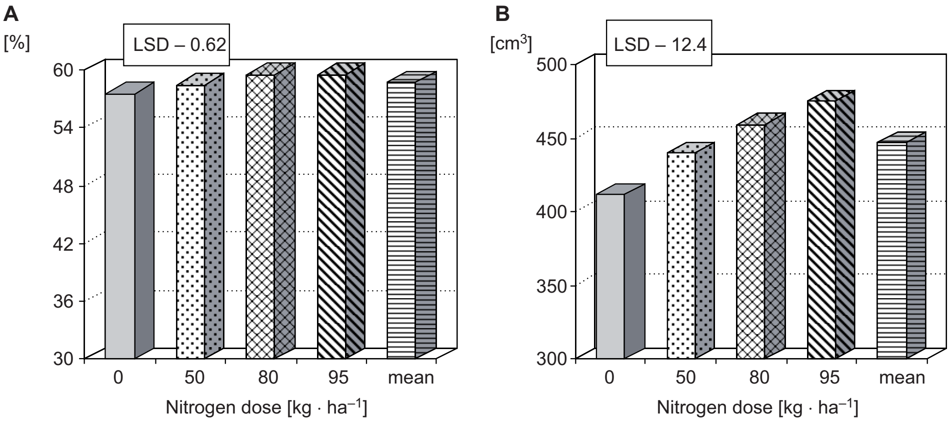

Fig. 3. Mean values of flour water holding capacity (A) and baking volume (B) depending on the nitrogen dose

The effect of the fertiliser factor on that flour character was inconsiderable, however it reached the level of significance, which is confirmed by the analysis of variance and coefficient of simple correlation (r = 0.96; Table 2). The dose of 80 kg N · ha^{-1} turned out to be optimal for flour water holding capacity when its second part (30 kg · ha^{-1}) was applied at the shooting phase (Fig. 3A). As reported by Cacak-Pietrzak et al [26], the highest flour water holding capacity was noted by applying 80 kg N · ha^{-1} (40 kg at the start of vegetation + 40 kg at the shooting phase) for the following cultivars: 'Almari', 'Kobra' and 'Panda'. Different results were reported only for 'Juma' for which the highest water holding capacity was also recorded for the treatment which involved the dose of 80 kgN · ha^{-1}, however split differently (40 kg at the start of vegetation + 30 kg by spraying at the shooting phase + 10 kg in a form of spray with microelements). Sulek et al [11] report on the highest, although non-significant, value of water holding capacity as a result of the application of 90 kg N · ha^{-1} (the second and third dose part applied in a fluid form at the shooting phase and over tillering). According to Podolska et al [8], increasing the nitrogen fertilisation dose to 120 kg · ha^{-1} resulted in an increase in flour water holding capacity, while further fertilisation increases did not affect that character, whereas Mazurek et al [24] claim that the value of that parameter depended neither on the nitrogen fertilisation dose nor on its application technique.

A direct quality indicator which demonstrates the baking value of wheat grain is the bread volume from test baking. In the present experiment the nitrogen fertilisation applied, similarly as reported in other research with winter wheat [4, 5], increased the

'Petrana' wheat baking volume (Fig. 3B). The highest value of that parameter (475 cm^3) was reported for N_{95} (50 kg at the start of the vegetation, 30 kg at the shooting phase, 15 kg over tillering) and it was significantly higher than the bread volume from the control, N_{50} and N_{80}, respectively, by: 13.3 %, 7.4 % and 3.4 %. Sulek et al [11], investigating the effect of different fertilisation doses and techniques in wheat on its quality parameters, did not observe a significant relationship between the above experimental factors and the bread volume. Similarly Mazurek et al [24] confirmed no effect of the nitrogen application method, however, increasing nitrogen fertilisation from 40 kg to 80 showed significance for that quality character.

Baking volume was significantly positively correlated with the content of gluten ($r = 0.91$), flour water holding capacity ($r = 0.81$) and the sedimentation index value ($r = 0.78$) (Table 2), which supports the claim that an increased share of high-molecule glutenin increases eg the bread volume [27]. Positive relationships of the bread volume with the content of gluten and sedimentation index value were also reported by other authors [4, 5].

Conclusions

1. After the application of the dose of 80 kg $N \cdot ha^{-1}$ there were noted significantly higher contents of total protein and wet gluten in grain as well as flour water holding capacity of the winter wheat cultivar investigated than the corresponding values determined after the nitrogen application at the dose of 50 kg $\cdot ha^{-1}$ and when compared with the control.

2. Varied nitrogen fertilisation, for the entire dose range applied, significantly determined mean sedimentation index values and bread volume in 'Petrana' winter wheat.

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DOLISTNE NAWOŻENIE AZOTEM JAKO CZYNNIK KSZTAŁTUJĄCY PARAMETRY TECHNOLOGICZNE PSZENICY OZIMEJ

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Abstrakt: W latach 2002–2005 w Zakładzie Doświadczalnym Uniwersytetu Rolniczego w Nitrze, w miejscowości Sládkovičovo – Nový Dvor, około 30 km od Nitry (Słowacja) przeprowadzono doświadczenie polowe, którego celem było określenie wpływu różnych dawek nawożenia azotem i sposobu jego aplikacji na wartość wybranych parametrów technologicznych w ziarnie i mące pszenicy ozimej odmiany Petrana. W przeprowadzonych badaniach zróżnicowane nawożenie azotem w całym zakresie stosowanych dawek powodowało wzrost zawartości białka ogólnego w ziarnie pszenicy ozimej odmiany Petrana. Jednak udowodniony statystycznie przyrost wartości badanej cechy uzyskano po zastosowaniu 80 kg N $\cdot$ ha^{-1} w stosunku do obiektu kontrolnego i obiektu, gdzie zastosowano 50 kg N $\cdot$ ha^{-1}. Zróżnicowane nawożenie azotem, w całym zakresie stosowanych dawek, powodowało korzystny wpływ na wartości badanych parametrów technologicznych. Jednak za optymalne dawki azotu dla najważniejszych wyróżników wartości wypiekowej, tj. wskaźnika sedymentacji i objętości pieczywa przyjęto 95 kg $\cdot$ ha^{-1} oraz zawartości mokrego glutenu i wodochłonności mąki – 80 kg $\cdot$ ha^{-1}.

Słowa kluczowe: pszenica ozima, nawożenie azotem, parametry technologiczne