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EFFECT OF GENOTYPE AND NITROGEN FERTILIZATION ON GRAIN YIELD AND QUALITY OF SPRING BARLEY INTENDED FOR HEALTH FOOD USE

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Abstract

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In the years 2007-2009, pot experiments on spring barley were carried out in greenhouse of Institute of Soil Science and Plant Cultivation-State Research Institute in Puławy, using the Mitscherlich pots. The following cultivars were compared: 'Basza', 'Conchita', 'Skarb', and 'Xanadu' in terms of their response to 3 levels of nitrogen fertilization (NH_4NO_3): 1, 2 and 3 g N / pot. Doses of 1 and 2 g N / pot was divided into two parts: 60% before sowing + 40% at the end of tillering, and the dose of 3 g N / pot was divided into three parts: 60% before sowing + 25% at the end of tillering + 15% before heading. Studied spring barley cultivars varied by grain yield size, grain yield structure traits and response to nitrogen doses. Cultivars 'Conchita' and 'Xanadu' had the higher grain yield and greater number of spikes per pot compared to 'Basha' and 'Skarb'. Cv. 'Skarb' was characterized by higher total dietary fibre and insoluble dietary fibre contents in grains than other cultivars. Cv. 'Xanadu' was characterized by the highest soluble dietary fibre content. 'Conchita' cultivar showed a higher (1-3) (1-4)-β-D-glucan content in the grain than other cultivars. With the increase of nitrogen levels to 3 g N/pot, there was obtained significant increase in grain yield and number of spikes per pot in all spring barley cultivars, but the decrease of 1000 kernel weight. Comparing to other cultivars, the highest yielding cultivars 'Conchita' and 'Xanadu' showed greater percentage increases in grain yield and number of spikes per pot under the influence of increasing nitrogen doses to 3 g N / pot. At 2 and 3 g N/pot doses, the highest dietary fibre and soluble beta-glucan contents in spring barley grains was stated in comparison with a dose of 1 g N/pot. With the increase of nitrogen dose to 3 g N/pot, there was showed significant increase in protein content in grain of all cultivars. Total dietary fibre, insoluble dietary fibre, and ash content in the grain of spring barley cultivars were not dependent on the nitrogen fertilization doses.

Key words: dietary fibre, β-glucan, protein, ash, barley, nitrogen dose

Abbreviations: IDF- insoluble dietary fibre, N-nitrogen, SDF- soluble dietary fibre, TDF-total dietary fibre

Introduction

Barley is a cereal of great importance in the crop structure in Europe and the World. Nowadays, the interest in using barley for food is renewed (Baik and Ullrich, 2008). Spring barley reaction to nitrogen dose, in terms of yield size, grain yield structure, and chemical composition of grains, depends on environment and cultivar properties (genotype) (Baethgen et al., 1995; Grashoff and Antuono, 1997). The protein content in grain increases with the increase of nitrogen doses (to various degrees in particular cultivars) even when the yield does not decrease. Nitrogen fertilization interacts with cultivar properties. This is due to the differences in morphological and physiological responses of cultivar (plant tillering ability, light requirements, the efficiency of nitrogen utilization, stiffness and flexibility of plants).

In the scientific literature concerning the effects of various agrotechnical factors and cultivar properties on barley grain quality, there is a wide range of information dealing with brewing traits (Gupta et al., 2010; Załuski et al., 2012). On the other hand, there is the lack of data about the barley grain quality used for food production (cereals, flakes). For many years,

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scientific studies show the need of diet verification form. It is considered that in diet the most important are low processed wholemeal cereal products (cereals, flakes, wholemeal bread). A special role is attached to the intake of dietary fibre (Willet, 2001). It is recommended that healthy adult consumers should consume 40g of dietary fibre a day, including at least 30% of soluble dietary fibre (DeVries, 2010; James et al., 2003). Actual consumption in this age group is much lower. High fibre cereal products of high soluble fraction content became so highly recommended and desirable food products. They can be obtained only from raw materials with a high content of dietary fibre as oats or barley (Rzedzicki and Wirkijowska, 2008). The functional properties of barley products are mainly due to the quantity and quality of dietary fibre contained in the grain.

Physiological impact of dietary fibre may be considered in terms of soluble (SDF) and insoluble fraction (IDF). Proper maintenance of IDF and SDF ratio in the diet ensures combined effect of both fractions and provides health and medical benefits including the comprehensive prevention. The insoluble fibre fraction (IDF) protects the human body primarily from gastrointestinal impairment. This fraction retains its structure in the colon, affects the motility of the intestines, and prevents constipation. Sorption properties of native fibre fraction IDF play a special role. Soluble dietary fibre fraction (SDF) shapes the diffusion properties of the small intestine environment. It slows down the diffusion process and absorption of cholesterol, especially LDL cholesterol and glucose (Brennan, 2005; McIntosh et al., 1991; Östman et al., 2006). Studies have shown the ability of soluble fibre, derived from barley and rich in (1,3) (1,4)-β-D glucans, to lower total cholesterol, LDL cholesterol and to increase the HDL:LDL ratio (McIntosh et al., 1991). It was also shown that increased consumption of barley's β-glucans of 3-8 g per day, reduced cholesterol levels by about 7-10%. Moreover, (1,3) (1,4)-β-D-glucan is an important bioactive compound that contributes to the ability of barley foods to help prevent type-2 diabetes (Dickin et al., 2011).

These indications point to a need for research on cereal grain quality and barley use for food purposes, especially for functional food production. This particularly concerns the selection of barley cultivars in terms of protein content, dietary fibre, fractional composition of fibre, and (1,3) (1,4)-β-D glucan contents. The modification ability of the functional grain quality should be also demonstrated by changing the most important agrotechnical and genetic factors.

The aim of the study was to compare the reaction of new spring barley cultivars to the increasing level of nitrogen fertilization in terms of dietary fibre, β-glucan, protein, and ash contents in grain.

The research hypothesis assumed unequal effect of nitrogen fertilization on dietary fibre, β-glucan, protein, and ash contents in spring barley grain. Different cultivars may differ in terms of β-glucan, protein and dietary fibre, and ash contents in grain.

Materials and Methods

In the years 2007-2009, pot experiments on spring barley were carried out in greenhouse of Institute of Soil Science and Plant Cultivation-State Research Institute in Puławy, using the Mitscherlich pots. The following cultivars were compared: 'Basza', 'Conchita', 'Skarb' and 'Xanadu' in terms of their response to 3 levels of nitrogen fertilization (NH_4NO_3): 1, 2 and 3 g N / pot. Doses of 1 and 2 g N/pot was divided into two parts: 60% before sowing + 40% at the end of tillering, and the dose of 3 g N/pot was divided into three parts: 60% before sowing + 25% at the end of tillering + 15% before heading. Moreover, mineral fertilization was used in doses of 0.8 g P, 1.7 g K, 0.4 g Mg, 50 mg Fe, 5 mg of B, and 3 mg Cu per pot. Sowing was made at the end of March. In two leaves phase, there were left 10 plants in a pot. Soil moisture was maintained at 60% of field water capacity. The experiment was established as a random design, in four replications.

After harvesting, there was determined the chemical composition of studied cultivars such as crude ash content (AACC, Method 08-01), crude protein (on the camera Kiel-Tec, Method, AACC 46-08), total dietary fibre (TDF) and its soluble (SDF) and insoluble fractions (IDF). There were also determined (1,3) (1,4)-β-D glucan content (AOAC, Method 991.43, AACC, Method 32-07, AACC, Method 32-21, AOAC Method 985.29, AACC, Method 32-05, AACC 32-23, AOAC 995.16) (AACC, Approved Methods of the American Association of Cereal Chemists, St. Paul, Minnesota, 2000).

The results were analyzed statistically using analysis of variance and the significance of differences was determined by Tukey's test ($P \leq 0.05$).

Results

There were significant differences in the grain yield between spring barley cultivars as well as between levels of nitrogen fertilization. The highest yielding cultivars were 'Conchita' and 'Xanadu' (Table 1). 'Xanadu' and 'Conchida' cultivars were characterized by the largest number of spikes per pot. Cv. 'Conchita' showed the highest 1000 kernel weight and cv. 'Skarb' the largest number of grains in spike. In all studied spring barley cultivars, the increase of nitrogen fertilization to 3 g N / pot resulted in a significant increase in grain yield and number of spikes per pot (Table 2). The use of high nitrogen doses resulted in small 1000 kernel weight of barley grain and in tendency to large number of grains per spike.

Reaction of spring barley cultivars to nitrogen fertilization level was unequal in terms of yield. Cultivars ‘Conchita’ and ‘Xanadu’ showed greater percentage of grain yield increase and number of spikes per pot under the influence of increasing nitrogen dose to 3 g N / pot (Tables 3 and 4).

In studied spring barley cultivars, the total dietary fibre content (TDF) ranged from 21.9 for cv. ‘Xanadu’ to 24.2% (d.w.) for cv. ‘Skarb’. Cv. ‘Skarb’ showed significantly higher dietary fibre content (TDF) compared to the other cultivars. The other three cultivars did not show the significant differences. Cv. ‘Skarb’ was characterized by the highest insoluble dietary fibre (IDF) of 18.7% and it was a significantly higher value compared to other cultivars (Table 5).

Cv. ‘Xanadu’ was characterized by significantly higher content of soluble fibre content (SDF) of 6.4% comparing to cv. ‘Skarb’ (Table 5).

In our study, the prebiotic content ranged from 3.99% in cv. ‘Xanadu’ to 4.69% in cv. ‘Conchita’ (Table 5). ‘Conchita’ cultivar had significantly higher prebiotic content comparing to all other cultivars.

Among tested cultivars the statistically significant differences in protein content were in grains of ‘Conchita’ and ‘Skarb’ cultivars, and there were from 12.1 to 13.5%, respectively (Table 5).

The influence of nitrogen fertilization level on the chemical composition of barley grain was also determined, especially on protein content. With the increase of nitrogen fertilization, increased protein content in barley grains, confirmed statistically (Table 6). At the lowest level of nitrogen fertilization, the protein content was 10.7%, whereas at the highest nitrogen level was 14.5%. The increase of nitrogen fertilization did not affect significantly the total content of dietary fibre (TDF) and its insoluble fraction (IDF) (Table 6).

The nitrogen fertilization level had a positive impact on the (1-3) (1-4)-β-D-glucan content. Throughout the experimental group, with the increase of nitrogen fertilization rate, there was observed the increase of the studied component, confirmed statistically. The (1-3) (1-4)-β-D-glucan content increases steadily with the nitrogen dose (Table 6). The reported tendency is particularly valuable in terms of functional characteristics of the raw material and intensive cultivation does not impair the quality parameters, on the contrary the (1-3) (1-4)-β-D-glucan content increases.

However, there are slight differences in the (1-3) (1-4)-β-D-glucan content among cultivars. They reacted ambiguously to the change of nitrogen fertilization. Cv. ‘Skarb’ was characterized by the significant increase in beta-glucan content in grain with the increase of nitrogen dose to 3 g N/pot. ‘Basha’ and ‘Xanadu’ cultivars also showed increasing trends in (1-3) (1-4)-β-D-glucan content, although not confirmed statistically significant for the second and third levels. Cv. ‘Conchita’ reacted quite differently. With the increase in nitrogen fertilization there was observed the decrease in (1-3) (1-4)-β-D-glucan content, although these differences were not statistically significant (Table 7).

Table 1
The size and structure of the grain yield of spring barley cultivars (2007-2009)

Cultivars	Grain yield, g/pot	Number of spikes per pot	Number of grains per spike	1000 kernel weight, g
Basza	63.8bc*	51.5b	23.9a	51.4b
Conchita	71.2a	55.1a	20.7b	55.1a
Skarb	59.7c	53.3ab	20.4b	53.3ab
Xanadu	66.5b	51.7b	19.6b	51.7b

* The results in columns marked with different letters differ significantly

Table 2
The size and structure of spring barley grain yield (cultivars averages) depending on nitrogen dose

Nitrogen dose, g/pot	Grain yield, g/pot	Number of spikes per pot	Number of grains per spike	1000 kernel weight, g
1	51.0c*	45.7c	20.7a	53.9a
2	65.9b	59.4b	20.8a	53.7a
3	79.1a	71.3a	21.7a	51.1b

* The results in columns marked with different letters differ significantly

Table 3
Grain yield of spring barley cultivars in g/pot (%) depending on nitrogen dose

Nitrogen dose, g/pot	Basza	Conchita	Skarb	Xanadu
1	52.1 (100)	51.2 (100)	51.5 (100)	49.1 (100)
2	65.0 (125)	70.2 (137)	61.4 (119)	67.2 (137)
3	74.4 (143)	92.5 (180)	66.3 (129)	83.3 (170)

Table 4
The number of spikes in spring barley cultivars per pot (%) depending on nitrogen dose

Nitrogen dose, g/pot	Basza	Conchita	Skarb	Xanadu
1	45.2 (100)	45.3 (100)	46.8 (100)	45.6 (100)
2	50.7 (112)	61.0 (137)	54.4 (116)	71.5 (157)
3	58.6 (130)	80.5 (178)	60.5 (129)	86.0 (188)

Studied cultivars did not differ significantly in terms of ash content (Table 5). During the study also reported no significant effect of nitrogen fertilization on the mineral content in grain (Table 6).

Discussion

In previous studies on 'old' spring barley cultivars, there were stated their unequal response to highest nitrogen doses. Weak tillering barley cultivars showed the highest grain yield increase and number of spikes per area at the highest nitrogen dose (Baethgen, 1995).

From standpoint of the human nutrition, it is very important not only the total dietary fibre content (TDF) but also its soluble fraction (SDF). Soluble fibre content (SDF) was varied among the cultivars.

Dietary fibre values obtained in our study were similar to those in the literature (Kawka et al., 1999). An important criterion of functionality of food barley grain is the ratio of dietary fibre SDF to total dietary fibre TDF. Studied spring barley cultivars were characterized by relatively high value of this parameter, as for hulled barley. SDF to TDF ratio ranged from 22.7% to 29.2% in cultivars 'Skarb' and 'Xanadu', respectively. These values are comparable to results reported by other authors (Baethgen et al., 1995; Kawka et al., 1999). 'Xanadu' is an interesting cultivar of barley because of the lowest TKW values, and the highest ratio of soluble fibre (SDF) to total dietary fibre (TDF).

The main functional barley quality parameter for food production is the content of valuable prebiotics such as (1,3) (1,4)-β-D glucans. Comparing to other cereals, barley has a very good parameters in terms of their content (Yalçin et al., 2007). β -glucan content in barley is comparable to oats. Andersson et al. (1999) stated that the (1-3) (1-4)-β-D-glucan content in hulled barley ranged from 3.7 to 5.4%.

From the point of view of cereal technology, protein content is a very important parameter, because with the increase of it also increases the vitreousness of grain increase and improves grouts extract. In this regard, studies confirm the existence of positive correlation between the nitrogen fertilization level and protein content observed also by other researchers (Idziak and Michalski, 2004).

From the viewpoint of hulled barley processing technology, these parameters are of less importance, because a significant part of total dietary fibre, especially IDF fraction (chaff), is removed during the hulling. In this case, they are

Table 7
The content of beta-glucans in barley grain depending on the cultivar and nitrogen dose

Nitrogen dose, g/pot	Basza	Conchita	Skarb	Xanadu
1	3.84b*	4.78a	3.70c	3.37b
2	4.34a	4.73a	4.02b	4.27a
3	4.40a	4.56a	4.29a	4.31a

* The results in columns marked with different letters differ significantly

Table 5
The content of total dietary fiber (TDF), soluble (SDF) and insoluble (IDF) and beta-glucan content, ash and crude protein in grain of spring barley cultivars

Cultivars	TDF	SDF	IDF	Beta-glucans	Ash	Protein
	% d.w.	% d.w.	% d.w.	% d.w.	% d.w.	% d.w.
Basza	22.6ab*	6.0ab	16.6b	4.16ab	2.21a	12.5bc
Conchita	22.4ab	5.9ab	16.5b	4.69a	2.19a	12.1c
Skarb	24.2a	5.5b	18.7a	4.00b	2.18a	13.5a
Xanadu	21.9b	6.4a	15.5b	3.99b	2.15a	12.8b

Table 6
The content of total dietary fiber (TDF), soluble (SDF) and insoluble (IDF) and beta-glucan content, ash and crude protein in grain of spring barley (cultivars averages) depending on nitrogen dose

Nitrogen dose, g/pot	TDF, % d.w.	SDF, % d.w..	IDF, % d.w.	Beta-glucans, % d.w.	Ash, % d.w.	Protein, % d.w.
1	22.3a*	5.7b	16.7a	3.92b	2.10a	10.7c
2	22.8a	6.4a	16.8a	4.34a	2.04a	13.0 b
3	23.2a	6.0ab	17.1a	4.39a	2.05a	14.5a

* The results in columns marked with different letters differ significantly
d.w. dry weight

not so important criteria for deciding the functional characteristics of the raw material.

The increase of nitrogen fertilization level had a positive impact on the soluble fibre content (SDF) and the differences were confirmed statistically. These results require confirmation in a subsequent experiment, because at the highest nitrogen fertilization level, a decline in SDF fraction was observed. The present results indicate that the dependence of the SDF content on fertilization level describes the second degree function with a maximum at the second level of nitrogen dose. In case of this changes confirmation, the high fertilization would have negative influence on functional characteristics of barley and should not be used.

It should be emphasized that cv. 'Conchita' was characterized by the highest (1-3) (1-4)-β-D-glucan content and from the point of view of this criterion, it is particularly valuable for food processing.

Conclusions

- Studied spring barley cultivars varied by grain yield size, grain yield structure traits and response to nitrogen dose. 'Conchita' and 'Xanadu' cultivars had the higher grain yield and greater number of spikes per pot compared to 'Basha' and 'Skarb' cultivars.
- 'Skarb' cultivar was characterized by higher total dietary fibre and insoluble dietary fibre contents in grains than other cultivars. Cultivar 'Xanadu' was characterized by the highest soluble dietary fibre content. 'Conchita' cultivar showed a higher (1-3) (1-4)-β-D-glucan content in the grain than other cultivars
- With the increase of nitrogen levels to 3 g N/pot, there was obtained significant increase in grain yield and number of spikes per a pot in all spring barley cultivars, but the decrease of 1000 kernel weight. Comparing to other cultivars, the highest yielding cultivars 'Conchita' and 'Xanadu' showed greater percentage increases in grain yield and number of spikes per pot under the influence of increasing nitrogen doses to 3 g N/pot.
- At 2 and 3 g N/pot doses, there was stated the higher dietary fibre content and soluble beta-glucan content in spring barley grains in comparison with a dose of 1 g N/pot. With the increase of nitrogen dose to 3 g N/pot, there was showed significant increase in protein content in grain of all cultivars. Total dietary fibre, insoluble dietary fibre, and ash content in the grain of spring barley cultivars were not dependent on the nitrogen fertilization doses.

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