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EFFECT OF FERTILIZATION AND VARIETY ON THE β-GLUCAN CONTENT IN THE GRAIN OF OATS

S t r e s z c z e n i e

The object of the study was to investigate the influence fertilization on the β-glucan content of the common oats varieties (Vendelin, Zvolen) and the naked oats varieties (Detvan, Avenuda). The trial was established in the years 2007 and 2008 in the potato growing area in the centre of Slovakia in Vígľaš-Pstruša. The field treatments were realized in natural conditions without irrigation with four variants of fertilization. Nitrogen fertilization was applied before sowing and foliar application of selenium together with nitrogen was done in the growth phase at the end of stooling (BBCH 29). The amount of β-glucan in the samples was determined by using the β-glucan assay kit (Megazyme, Ldt. Ireland). The total average of β-glucan content in the experiment was 4.08 %. The naked oats varieties reached higher content of β-glucan, when we compare it with the common oats. The variety Avenuda reached highest of β-glucan content (5.20 %). The nitrogen fertilization together with selenium fertilization statistically significantly increased the content of this polysaccharides. The influence of a particular year was statistically significant in β-glucan content.

Słowa kluczowe: fertilization, nitrogen, selenium, oats, variety, β-glucan

Introduction

Soluble fiber when added to the daily diet, tends to lower serum low-density lipoprotein cholesterol and total blood cholesterol [3, 9] and this results in the reduction of the risk of coronary heart disease [8]. β-glucan is the main soluble component of barley and oat fiber. β-glucan is a collective term for high molecular weight polymers of glucose linked by β(1-3) and β(1-4) glycosidic bonds. This health-beneficial fiber was found in the cell walls of barley, oat, wheat, rye, maize, rice, sorghum and millet [11].

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With oat and barley grains, β-glucan is found mainly in the endosperm and the subaleurone layer [14, 18]. As compared to other cereals, barley and oat have relatively high level of β-glucan. Barley contains between 20 and 100 g β-glucan·kg^{-1} and oat contains between 25 and 66 g β-glucan·kg^{-1} [11]. Oat has been intensively studied as a source of dietary fiber for human diet. Heritability of β-glucan content was estimated to have ranged from 0.27 to 0.58. β-glucan content is affected by enviromental factors including soil nitrogen level and precipitation. Although *genotype x enviroment* interaction is sometimes a significant source of variation for β-glucan content, the ranking of genotypes is generally consistent over enviroments. The development of oat cultivars with greater groat β-glucan contents should increase the nutritional and economic value of the oat crop [2].

The object of the study was to find out differences in β-glucan content of the common oats and naked oats varieties grown one location in two years with different variants of fertilization. The result of the investigation should be determination of the best of fertilization which provides (guarantee) considerable content of health-beneficial polysaccharides in grain growing oats.

Material and methods

The fertilization trial was established in the years 2007 and 2008 in the potato growing area in the centre of Slovakia in Vígľaš-Pstruša. The common oats varieties (Vendelin, Zvolen) and the naked oats varieties (Detvan, Avenuda) were sown in this experiment. The sowing was implemented in a sowing succession after red clover with the crop area of 10 m^2 in four repetitions and the sowing of 5.0 million germinant grains per 1 ha. The soil type is pseudogley with an acid soil reaction and the average supply of phosphorus and potassium. Its agrochemical parameters are shown in Tab. 1.

Respecting the content of inorganic nitrogen in soil, different doses of nitrogenous fertilization were applied together with selenium, with the identical phosphoric and potassium nourishment at the substituting fertilization level [10]. Phosphoric fertilization (in form of hypercorn 26 % P_2O_5) and potassium fertilization (in form of potassium salt 60 % K_2O) were applied unrepeatedly in the autumn. Nitrogen in form of amonium nitrate (27 % N) was applied before sowing on planned yield 4 t.ha^{-1}. During vegetation period – at the end of the stooling period (BBCH 29) we foliarly applied nitrogen on the crop area (15 kg.ha^{-1}) in form of DAM-390 and selenium in form of selenate sodium (Na_2SeO_4). Nourishment variants used in the experiment are shown in Tab. 2.

T a b l e 1

Basic agrochemical soil parametres.

Soil Analysis	Content in the year 2007 parcel - Kostolisko I	Content in the year 2008 parcel - Tri duby E
pH_{KCl}	5.12	6.35
Nan [mg.kg^{-1}]*	15.4*	14.2*
P [mg.kg^{-1})]	55.9	72.5
K [mg.kg^{-1}]	130.0	119.5
Mg [mg.kg^{-1}]	226.0	242.5
Ca [mg.kg^{-1}]	1625.0	2437.5
Humus [%]	1.03	1.52

pH_{KCl}-(potentiometrically in 1.0 M KCl extract); Nan- [numerically as the sum of $N–NH_4^+$ + $N–NO_3^-$ ($N–NH_4^+$ colorimetry, Nesslerovo reagent and $N–NO_3^-$ colorimetry, acid phenol 2,4-disulphonic)]; P-(colorimetry, Mehlich II 2007; spectrophotometrically, Mehlich III - 2008); K-(Flame photometry, Mehlich II - 2007; flame emission spectrophotometry, Mehlich III - 2008); Ca-(Flame photometry, Mehlich II 2007; atomic spectrophotometry, Mehlich III - 2008); Mg-(atomic absorption spectrometry, Mehlich II - 2007; atomic spectrophotometry, Mehlich III - 2008); humus-(as oxidizing carbon, Tjurin);

* - the content of Nan in soil in spring just before the experiment

T a b l e 2

Fertilization variants in the experimental in the year 2007 and 2008.

Variant	Fertilization	Real amount of fertilizer applied in 2007				Real amount of fertilizer applied in 2008			
		N	P	K	Se	N	P	K	Se
		kg·ha^{-1}			g·ha^{-1}	kg·ha^{-1}			g·ha^{-1}
1.	N_0	-	24	96	-	-	12	96	-
2.	N_1	47[AN]	24	96	-	54[AN]	12	96	-
3.	N_2	35[AN]	24	96	-	40[AN]	12	96	-
4.	N_1+15	47[AN]+15[DAM390]*	24	96	-	54[AN]+15[DAM390]*	12	96	-
5.	N_2+15	35[AN]+15[DAM390]*	24	96	-	40[AN]+15[DAM390]*	12	96	-
6.	N_1+Se	47[AN]	24	96	5*	54[AN]	12	96	5*
7.	N_2+Se	35[AN]	24	96	5*	40[AN]	12	96	5*
8.	N_1+15+Se	47[AN]+15[DAM390]*	24	96	5*	54[AN]+15[DAM390]*	12	96	5*
9.	N_2+15+Se	35[AN]+15[DAM390]*	24	96	5*	40[AN]+15[DAM390]*	12	96	5*

$N_{1,2}$ – nitrogen applied before sowing * – nitrogen and selenium applied during vegetation at the end of the stooling period 29 BBCH

AN-amonium nitrate

T a b l e 3

The meteorological characteristic of experimental place in the year 2007 and 2008.

Specyfication	January	February	March	April	May	June	July
50 years average of temperature [1951-2000] [^{0}C]	-3.80	-1.50	2.80	8.40	13.10	16.30	17.80
Average of temperature in 2007 [^{0}C]	2.83	2.79	6.11	10.54	15.14	18.47	19.97
Average of temperature in 2008 [^{0}C]	0.10	1.78	3.97	9.67	14.51	18.41	18.74
50 years average of precipitation [1954-2003] [mm]	28.10	28.50	29.80	46.70	63.90	85.20	75.60
Average of precipitation in 2007 [mm]	70.80	35.40	53.50	0.80	95.80	106.50	20.30
Average of precipitation in 2008 [mm]	29.90	19.90	49.60	36.30	64.20	59.40	117.50

The amount of β-glucan in the samples was determined by using enzymatic kit Mixed-linkage β-glucan assay procedure (McCleary Method) K-BGLU 04/06 (Megazyme International Ireland, Ltd) [12]. The results were statistically evaluated by Analysis of Variance in program KANRO.

Research and discussion

The growing conditions of oats strongly influence the content of β-glucan in his cell walls. The Ganssmann [4] set down the average content of β-glucan to 4.7 % in German oats varieties. Our analysis showed β-glucan content of oats ranging from 2.50 to 5.95 %.

All determined results of β-glucan content in analysed oats varieties' grain were analysed using the analysis of variance aiming at the determination of the influence of fertilization variants, the influence of variety and particular year on the content of β-glucan in the grain of oats. The results revealed that the content of β-glucan in the grain of oats was significantly influenced by fertilization, variety and the experimental year. The interactions of *fertilization x variety*, *fertilization x year* and *variety x year* were statistically significant. The interaction *variety x year* influences the content of β-glucan to the highest extent. Our results are identical with the results of Sgrulletta et al. [16], who states that the interaction *variety x year* significantly influenced the content of total β-glucanin in the group of naked oats from different countries of the world. Also Givens et al. [5] observed the influence of variety and agronomical and enviromental factors on chemical content of naked and common oats varieties. They found out that the interaction *variety x year* simultaneously with the optimum amount of

nitrogen the most significantly influenced the chemical composition and nutrition value of oats.

All research varieties in their interaction *variety x year* had higher β-glucan content in the year 2008. Only Zvolen Variety showed significantly high increase, while with other varieties the increase was not significant.

In interaction *fertilization x year* the high content of β-glucan was reached in all variants of fertilization. Looking at varieties on average, only the variant without treatment (var.1) and variant 5 (N_2+15) increased significantly.

T a b l e 4

The content of β-glucan in the oats grain.

Variant	Fertilization	Variety	Year 2007		Year 2008		Variety	Year 2007		Year 2008	
			Content of β-glucan					Content of β-glucan			
			Abs.	Rel.	Abs.	Rel.		Abs.	Rel.	Abs.	Rel.
1	0	Vendelin	3.31	100.0	3.49	100.0	Zvolen	3.06	100.0	3.22	100.0
2	N1	Vendelin	2.99	90.3	3.40	97.4	Zvolen	3.50	114.6	3.47	107.5
3	N2	Vendelin	3.56	107.8	3.18	91.0	Zvolen	2.53	82.9	3.63	112.7
4	N1+15	Vendelin	2.78	84.0	3.63	104.0	Zvolen	2.93	95.9	3.72	115.4
5	N2+15	Vendelin	2.75	83.2	3.23	92.7	Zvolen	3.00	98.2	3.88	120.3
6	N1+Se	Vendelin	3.77	114.1	3.22	92.3	Zvolen	3.74	122.4	3.92	121.7
7	N2+Se	Vendelin	3.42	103.5	2.99	85.6	Zvolen	3.66	119.9	3.82	118.4
8	N1+15+Se	Vendelin	3.58	108.2	3.67	105.2	Zvolen	3.25	106.3	4.45	137.9
9	N2+15+Se	Vendelin	3.52	106.6	3.41	97.7	Zvolen	3.26	106.5	3.62	112.2
Average			3.30	-	3.36	-		3.21	-	3.75	-
1	0	Detvan	4.14	100.0	4.51	100.0	Avenuda	4.42	100.0	5,57	100.0
2	N1	Detvan	4.10	99.2	4.52	100.2	Avenuda	4.89	110.7	5.14	92.3
3	N2	Detvan	4.10	99.0	3.97	87.9	Avenuda	5.06	114.7	5.37	96.4
4	N1+15	Detvan	4.40	106.2	4.14	91.8	Avenuda	5.94	134.5	4.93	88.6
5	N2+15	Detvan	4.07	98.4	4.41	97.7	Avenuda	4.66	105.5	4.98	89.4
6	N1+Se	Detvan	4.70	113.5	4.28	94.8	Avenuda	5.38	121.9	5.33	95.6
7	N2+Se	Detvan	4.16	100.6	4.57	101.3	Avenuda	5.95	134.8	5.42	97.4
8	N1+15+Se	Detvan	4.94	119.3	4.10	91.0	Avenuda	4.80	108.8	5.26	94.4
9	N2+15+Se	Detvan	4.39	106.0	4.59	101.7	Avenuda	5.62	127.3	4.81	86.3
Average			4.33	-	4.34	-		5.19	-	5.20	-

HD-p-0.05 content of β-glucan: fertilization 0.2839; variety 0.1567; year 0.0846; fertilization x variety 0.7023; fertilization x year 0.4515; variety x year 0.2615 HD-p-0.01 content of β-glucan**:** fertilization 0.3286; variety 0.1899; year 0.1111; fertilization x variety 0.7799; fertilization x year 0.5101; variety x year 0.3042

A lot of research papers have been written about nitrogen fertilization and its influence on the quality. The results of these studies reveal that nitrogen significantly influence contents of protein, β-glucan and fat of an oats grain [1, 7, 13, 15]. All variants of fertilization considering the average of years 2007 and 2008 influence the content of β-glucan of an oats grain. The influence was both positive and negative. The variants 3 and 5 showed negative influence, as lower nitrogen fertilization before sowing 35 kg.ha^{-1} (year 2007) and 40 kg.ha^{-1} (year 2008) was applied. On the other hand selenium application during vegetation (amount 5 g.ha^{-1}) together with nitrogen fertilization increased β-glucan content in grain in all the variants (in average of years and varieties, variants 6, 7, 8, 9). The significant increase in β-glucan content was confirmed with the variants 6, 7 and 8 as compared to the controlled variant without treatment; the mentioned increase was ranging from 7.37 to 8.29 % (Fig. 1).

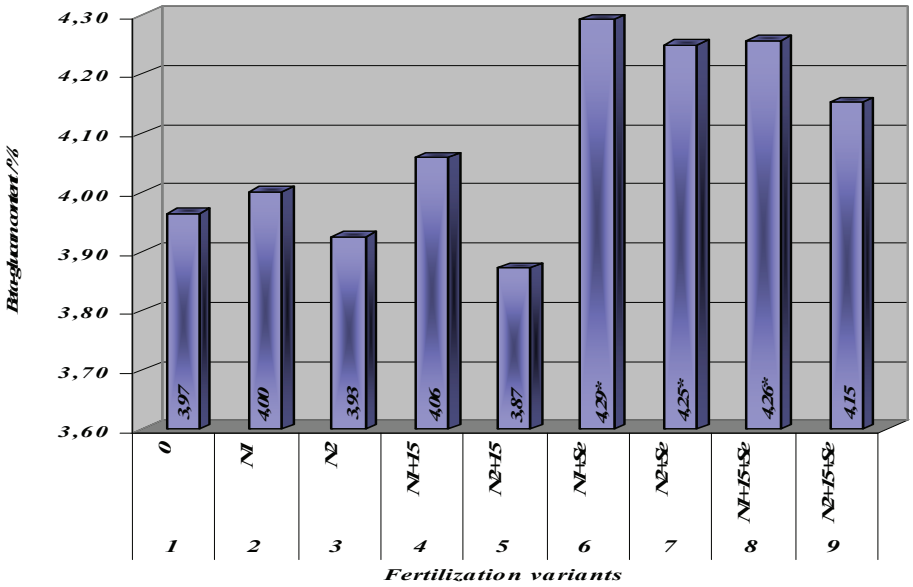

Fig. 1. The influence of fertilization on β-glucan content in oats grain in average of years and varieties.

Šterba and Moudrý [17] found out that naked oats genotypes have higher content of β-glucan as compared to the common oats genotypes and thus confirming that common oats has on average lower content of β-glucan. This information also confirms the results of our experiment because common oats varieties Vendelin and Zvolen (there were statistically insignificant differences in content of β-glucan between these common oats varieties) showed significantly lower β-glucan content in grain in comparison with naked oats varieties Detvan and Avenuda. The varieties of naked oats

showed statistically significantly high difference and the naked oats variety Avenuda itself reached (considering the average of years 2007 and 2008) the highest average β-glucan content of 5.20 % (Fig. 2).

As it has already been stated, the influence of genotype on β-glucan content is higher than the influence of enviromental factors [6]; unlike the influence of a particular year, where Šterba and Moudrý [17] revealed statistically significant difference. Statistically significant difference of the two years' trial (2007 and 2008) was also confirmed in our experiment. The average content of β-glucan in experimental varieties in the year 2008 was significantly higher in comparison with the year 2007.

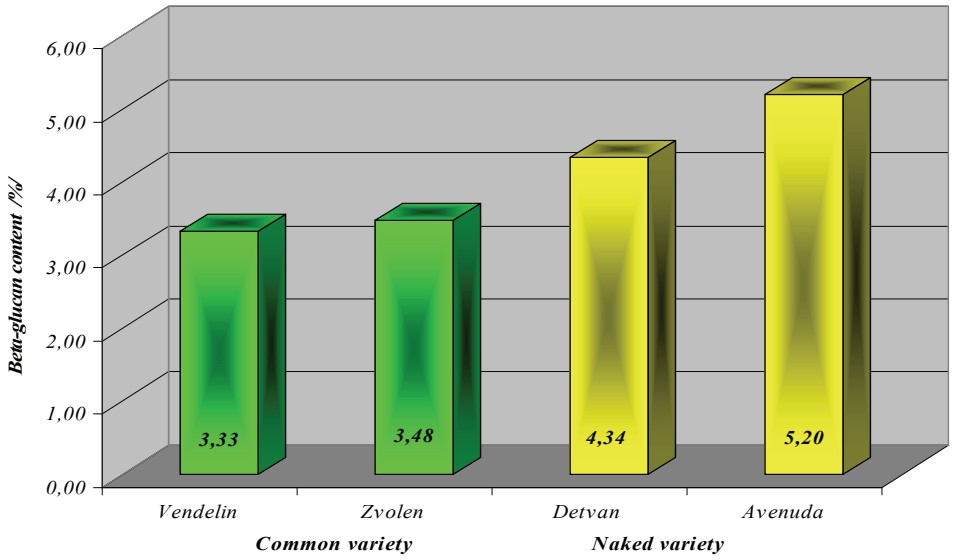

Fig. 2. The influence of variety on β-glucan content in grain in average of years (2007, 2008).

Conclusion

To sum up the results of the two-year field trial, in which we were observing the influence of fertilization on β-glucan content in the grain of common oats and naked oats, we have come up with the following conclusion:

- the total average of β-glucan content in the experiment was 4.08 %,
- naked oats varieties showed higher content of β-glucan if we compare it with the common oats,
- nitrogen fertilization combined with selenium fertilization statistically significantly increased the content of the observed polysaccharides,
- our results have shown and thus we can recommend optimum fertilization (considering β-glucan content) for common oats varieties the one, in which nitrogen

was applied in higher amount before sowing and selenium was applied foliarly during vegetation with or without nitrogen (variants 6, 8),

– it is not possible to determine explicitly the most suitable variant of fertilization for naked oats from the gained results; but strong negative influence on β-glucan content in grain could be observed with the variant of fertilization with lower nitrogen amount applied before sowing together with nitrogen applied during vegetation (15 $kg \cdot ha^{-1}$),
– the influence of a particular year on β-glucan content was statistically significant.

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