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CONTENT OF MINERALS, TOTAL PROTEIN AND WET GLUTEN IN GRAIN OF SPRING WHEAT DEPENDING ON CROPPING SYSTEMS

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Abstract

A strict field experiment was established in 1988 at the Uhrusk Experimental Station, belonging to the University of Life Sciences in Lublin, south-eastern Poland. Results presented in this manuscript originate from the years 2006-2009, namely from 5 crop rotations and from a 16-20-year cereal monoculture. In a two-factor experiment, spring wheat of the cultivar Opatka was sown in different cropping systems. The first order factor in the experiment was the cropping system (CS): crop rotation (CR), and monoculture (M), whereas the second order factor were nitrogen doses: 90 kg N ha^{-1}, and 150 kg N ha^{-1}. The study demonstrated that wheat grain collected from CR was characterized by higher content of P, Ca, Fe and Zn compared to the grain harvested from M. Fertilization with 90 kg N ha^{-1} increased significantly the content of P, K, Ca, Fe and Zn in the grain compared to the fertilization with 150 kg N ha^{-1}. The cropping systems (CS) and nitrogen doses were observed to differentiate the content of protein and gluten in the grain. A higher content of protein was determined in the grain originating from M than in the grain harvested from CR. The content of protein and gluten was increased by the fertilization dose of 150 kg N ha^{-1} compared to the dose of 90 kg N ha^{-1}.

Key words: chemical composition, spring wheat, crop rotation, monoculture.

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ZAWARTOŚĆ SKŁADNIKÓW MINERALNYCH, BIAŁKA OGÓŁEM I GLUTENU MOKREGO W ZIARNIE PSZENICY JAREJ W ZALEŻNOŚCI OD SYSTEMU UPRAWY

Abstrakt

Ścisłe doświadczenie polowe założono w 1988 r. w Gospodarstwie Doświadczalnym Uhrusk należącym do Uniwersytetu Pryrodniczego w Lublinie. Prezentowane w pracy wyniki pochodzą z lat 2006-2009, tzn. 5 rotacji płodozmianu i 16-20-letniej monokultury zbożowej. W doświadczeniu 2-czynnikowym wysiewano pszenicę jarą odmiany Opatka w różnych systemach uprawy roślin. Czynnikiem pierwszego rzędu były systemy uprawy roślin: płodozmian i monokultura; czynnikiem drugiego rzędu – dawki azotu: 90 kg N ha^{-1}, 150 kg N ha^{-1}.

Wykazano, że ziarno pszenicy zebrane z płodozmianu zawierało więcej P, Ca, Fe i Zn niż pochodzące z monokultury. Nawożenie 90 kg N ha^{-1} istotnie wpływało na zwiększenie zawartości P, K, Ca, Fe i Zn w ziarnie, w stosunku do 150 kg N ha^{-1}. Systemy uprawy roślin oraz dawki N różnicowały zawartość białka i glutenu w ziarnie. Więcej białka zawierało ziarno pochodzące z monokultury niż płodozmianu. Zawartość białka i glutenu wzrastała pod wpływem dawki 150 kg N ha^{-1}, w stosunku do dawki 90 kg N ha^{-1}.

Słowa kluczowe: skład chemiczny, pszenica jara, płodozmian, monokultura.

INTRODUCTION

The quality and mineral composition of wheat grain depends on genotype, agro-climatic conditions and agrotechnology (Ranhort et al. 1995, Ruibal-Mendieta et al. 2005, Zeb et al. 2006). Khan and Zeb (2007) as well as Chowdhry et al. (1995) demonstrated significant differences in the chemical composition of various cultivars of wheat grain, which were due to different agro-climatic conditions and agrotechnology applied. As reported by Morris et al. (2009), the content of ash in grain was affected to a greater extent by the course of weather during wheat maturation than by its genotype. In the opinion of Araus et al. (1998), the highest concentrations of minerals are typical of grain exposed to draught at the early stage of maturation. In turn, Paris and Gavazzi (1972) as well as Eser et al. (1997) report that the chemical composition of grain is determined by the type of soil and its fertilization. Furthermore, Woźniak and Makarski (2012), and Kraska (2011) noted a higher content of ash in the grain of wheat sown in the ploughless than in the ploughing system. Habitat conditions and cultivar preferences also affect the content of protein and gluten in wheat grain (Morris et al. 2009). In a study by Peltonen and Virtanen (1994), high doses of nitrogen increased the protein content of grain. In turn, Woźniak (2007) demonstrated a higher content of protein and gluten in grain harvested from a crop rotation than from a monoculture.

Considering the above, the aim of this study was to evaluate the effect of cropping system and different doses of nitrogen fertilization on the chemical composition and quality of spring wheat grain.

MATERIAL AND METHODS

The experimental material was grain of spring wheat cv. Opatka from a crop rotation experiment established in 1988 at the Uhrusk Experimental Station belonging to the University of Life Sciences in Lublin, south-eastern Poland. The results presented in this manuscript originate from the years 2006-2009, namely from 5 crop rotations and from a 16-20-year cereal monoculture. The design of a longitudinal experiment is presented in Table 1. The cultivar Opatka belongs to high quality wheats characterized by good milling quality, very good flour strength and high resistance to sprouting.

Table 1

Design of a longitudinal field experiment

Rotation	Period	Crop rotation (CR)	Monoculture (M)
I	1988-1992	P - WTr - Pe - WTr	WTr
II	1992-1996	P - WTr - Pe - WTr	WTr
III	1997-2000	P - STr - Pe - STr	STr
IV	2001-2005	P - WW - Pe - WW	WW
V	2006-2009	Pe - SW - Pe - SB	SW

P – potato, WTr – winter triticale, Pe – peas, STr – spring triticale, WW – winter wheat, SW – spring wheat, SB – spring barley.

The experiment was established on Rendzina soil formed from limestone of light clay, rich in available forms of phosphorus (2.14 mg P kg^{-1}) and potassium (2.37 mg K kg^{-1}), and with pH_{KCl} =7.2. In this soil, the content of inorganic nitrogen (N) was 1.03 g kg^{-1}, whereas that of organic carbon (C) reached 7.60 g kg^{-1}. A two-factor experiment was established with the method of randomized sub-blocks with plots measuring 15 m^2. The first order factor was a cropping system (CS): crop rotation (CR), and monoculture (M), whereas the second order factor were nitrogen doses: 90 kg N ha^{-1}, and 150 kg N ha^{-1}. The dose of 90 kg N ha^{-1} was applied as follows: 50 kg N ha^{-1} before sowing, 20 kg N ha^{-1} at the 22/23 stage (ZADOKS et al. 1974), followed by 10 kg N ha^{-1} (32/33 stage) and 10 kg N ha^{-1} (52/53 stage). The fertilization with 150 kg N ha^{-1} was applied in the same terms, with respective broadcasting doses of 70, 30, 30 and 20 kg N ha^{-1}.

The soil tillage for spring wheat was typical of the ploughing system and included pre-winter ploughing in the autumn and cultivation treatments in the spring. Plant protection was the same on all the plots and involved eradication of fungal diseases with Alert 375 SC fungicide (flusilazole + carbendazim) (32/33 stage) and Tilt Plus 400 EC (propiconazol + fenpropidin) (53/54 stage). Weed eradication in wheat crop was performed with the use of Chwastox Trio 540 SL herbicide (MCPA + mecoprop + dicamba) (23/24 stage).

Determinations of the content of mineral components in wheat grain were conducted after dry mineralization of the samples at a temperature of 600°C. The resultant ash was dissolved in 5 ml of 6M HCl, then each sample was filled up to the volume of 50 ml with redistilled water. Measurements were carried out with the method of Atomic Absorption Spectrometry with excitation in an acetylene-air flame in a UNICAM 939 apparatus. Protein and gluten were determined by the near-infrared (NIR) method using an Inframatic 9200 grain analyzer.

The data were analyzed statistically using the analysis of variance (ANOVA), and the means were compared by *F*-test protected LSD values calculated for $P < 0.05$ and $P < 0.01$. The information on agro-climatic conditions is presented in Table 2.

Table 2

Agro-climatic conditions at the Experimental Station in Uhrusk

Years	Months					Total or mean
	March	April	May	June	July	
Precipitation (mm)						
2006	36.2	32.0	98.8	35.2	47.6	249.8
2007	44.4	24.4	98.8	96.0	156.8	420.4
2008	50.0	49.0	69.0	38.0	117.0	323.0
2009	106.9	27.0	81.5	169.3	42.7	427.4
1963-2010	29.3	40.8	64.2	72.6	79.8	286.7
Air temperature (°C)						
2006	-2.2	8.8	13.5	17.0	21.5	11.7
2007	5.7	8.2	14.9	18.5	19.2	13.3
2008	3.8	8.3	13.7	17.9	18.2	12.4
2009	1.0	10.0	13.1	16.4	20.0	12.1
1963-2010	1.2	7.8	13.6	16.7	18.4	11.5

RESULTS

Contents of minerals in wheat grain were differentiated by nitrogen fertilization (Table 3). The dose of 150 kg N ha^{-1} increased significantly ash content of the grain (by 0.146 g kg^{-1} d.m.), compared to the dose of 90 kg N ha^{-1}. The content of phosphorus (P) in grain was found to depend on the cropping system (CS) and nitrogen (N) doses. The grain harvested from CR was characterized by a higher content of P (by 0.102 g kg^{-1} d.m.) than the

Table 3

Mineral composition of spring wheat grain (mean of 2006-2009)

Variable	Total ash (g kg^{-1} d.m.)	P (g kg^{-1} d.m.)	K (g kg^{-1} d.m.)	Mg (g kg^{-1} d.m.)	Ca (g kg^{-1} d.m.)	Mn (g kg^{-1} d.m.)	Fe (g kg^{-1} d.m.)	Zn (g kg^{-1} d.m.)
Crop rotation	18.18	2.59	2.82	1.05	0.59	23.69	26.20	19.22
Monoculture	18.25	2.48	3.56	1.06	0.54	24.23	24.68	15.99
90 kg N ha^{-1}	17.54	2.61	3.25	1.07	0.57	23.76	26.11	18.36
150 kg N ha^{-1}	18.88	2.46	3.13	1.04	0.56	24.16	24.77	16.85
LSD values								
Cropping systems	n.s	0.08*	0.23**	n.s.	0.03*	0.38**	0.76**	2.05**
Nitrogen doses	0.40**	0.12**	n.s.	n.s.	n.s.	0.27*	0.51*	1.31*
Cropping systems x nitrogen doses	n.s.	n.s.	0.39*	n.s.	n.s.	n.s.	n.s.	n.s.

n.s.: not significant; *P < 0.05 and **P< 0.01

grain originating from M. Also the fertilization dose of 90 kg N ha^{-1} increased (by 0.146 g kg^{-1} d.m.) P content of the grain, compared to the dose of 150 kg N ha^{-1}. The CS significantly differentiated also the content of potassium (K). In the grain originating from M, the content of K was higher (by 0.743 g kg^{-1} d.m.) than in that from CR. Also the CS x N interaction was observed to significantly affect K content of the grain. On CR plots the dose of 90 kg N ha^{-1} was increasing the content of K, compared to the dose of 150 kg N ha^{-1}. The content of magnesium (Mg) was at a similar level in CR and M plots and at fertilization doses of 90 and 150 kg N ha^{-1}. Also the CS x N interaction did not affect this parameter. In turn, calcium (Ca) content of the grain was differentiated by the cropping systems (CS). In the grain originating from CR the content of Ca was significantly higher than in the grain from the monoculture. The content of manganese (Mn) in wheat grain was differentiated by both CS and N doses. In the grain of wheat harvested from M, the content of Mn was higher (by 0.537 mg kg^{-1} d.m.) than in the grain from CR. Also the fertilization dose of 150 kg N ha^{-1} was observed to significantly increase Mn content of the grain (by 0.403 mg kg^{-1} d.m.), compared to the dose of 90 kg N ha^{-1}. The content of iron (Fe) in wheat grain depended on both CS and N doses. The grain of wheat harvested from CR was significantly richer in Fe than the grain originating from M. Also the fertilization dose of 90 kg N ha^{-1} had a significant effect on Fe content increase in the grain, when compared to the dose of 150 kg N ha^{-1}. Likewise zinc (Zn) content, which was significantly higher in the grain originating from plots with CR than with M. In turn, the nitrogen dose of 90 kg N ha^{-1} was increasing the content of this element in the grain, unlike the dose of 150 kg N ha^{-1}.

Out of the mineral components of the grain, the greatest variability was noted for K, Fe and Zn (Table 4). The content of K in the grain was characterized by higher variability (VC%) in CR than in M as well as on plots fertilized with the nitrogen dose of 150 kg N ha^{-1} than with 90 kg N ha^{-1}. In the case of Fe, higher VC values were determined in the grain harvested from M than from CR, and from plots fertilized with 90 kg N ha^{-1} than with 150 kg N ha^{-1}. Finally, Zn was characterized by over 2-fold higher value of VC in the grain from M than from CR.

The content of total protein in wheat grain depended on both CS and N doses (Table 5). The grain harvested from the monoculture (M) was characterized by a higher (by 0.9%) content of protein than the grain from crop rotation (CR). Also the fertilization dose of 150 kg N ha^{-1} was increasing protein content of the grain (by 0.5%) compared to the dose of 90 kg N ha^{-1}. In contrast, the content of gluten in the grain was determined only by nitrogen doses. A significantly higher content of gluten was noted in the grain of wheat fertilized with the nitrogen dose of 150 kg N ha^{-1} than with 90 kg N ha^{-1}.

Table 4

Variation coefficients (VC%) of the mineral composition of spring wheat grain

Variable	Total ash	P	K	Mg	Ca	Mn	Fe	Zn
Crop rotation	5.10	3.53	17.73	7.06	4.88	4.74	14.01	11.42
Monoculture	5.08	4.46	14.21	5.54	5.44	6.49	17.98	24.00
90 kg N ha^{-1}	3.90	2.83	18.57	6.72	7.46	6.26	19.74	19.83
150 kg N ha^{-1}	2.71	3.93	21.04	5.54	6.27	5.21	10.57	19.47

Table 5

Content of total protein and wet gluten in spring wheat grain (mean of 2006-2009)

Variable	Total protein		Wet gluten	
	mean (%)	VC (%)	mean (%)	VC (%)
Crop rotation	13.4	3.3	28.3	9.0
Monoculture	14.3	4.7	29.2	7.9
90 kg N ha^{-1}	13.6	5.9	28.5	10.0
150 kg Nha^{-1}	14.1	3.6	30.2	7.2
LSD values				
Cropping systems	0.4**	-	n.s.	-
Nitrogen doses	0.4**	-	1.5*	-
Cropping systems x nitrogen doses	n.s.	-	n.s.	-

*designations as in Table 3; VC – variation coefficient

DISCUSSION

The content of mineral components in wheat grain depended on both the cropping systems (CS) and nitrogen doses. In research by Kraska (2011), the content of ash in wheat grain was determined by soil tillage and skimmed intercrops. Ash content was also affected by cropping systems. Woźniak (2007) showed that grain of winter wheat originating from a monoculture was characterized by a higher ash content than grain harvested from a crop rotation. It may be speculated that this was due to a high contribution of fine grain with the poorly developed endosperm and a low 1000 kernel weight (Woźniak 2007). In the reported study, the content of ash in grain harvested from CR and M was at a similar level. The content of minerals in the grain was also affected by fertilization. The grain from plots fertilized with the nitrogen dose of 150 kg N ha^{-1} was characterized by a higher ash content than the grain from plots fertilized with 90 kg N ha^{-1}. Similar dependencies were demonstrated in studies by JACKOWSKA and BORKOWSKA (2002), PARIS and GAVAZZI (1972) as well as WOŹNIAK and MAKARSKI (2012). The cropping systems (CS) were found to exert a significant effect on the content of minerals in the grain. Higher content of P, Ca, Fe and Zn was assayed in the grain harvested from the crop rotation (CR) system than from the monoculture (M). It may be presumed that this was due to weaker absorption of minerals by plants from soil in the monoculture than in the crop rotation. As reported by COOK (1981) as well as STRUIK and BONCIARELLI (1997), under monoculture conditions the root system of cereals is more poorly developed than under crop rotation, which is linked with infestation of roots and the stem base with fungal diseases. WOŹNIAK and MAKARSKI (2012) demonstrated that the content of minerals in grain was also affected by preceding crops. Wheat harvested from plots after soybean was characterized by a higher content of ash, K and Mn than wheat originating from plots after pea. In contrast, wheat sown after pea had more Ca, Fe and Zn. Also KRASKA (2011) observed changes in the mineral composition of wheat grain after different preceding crops. The grain harvested after red clover was richer in Fe than the grain sown after other plants. In turn, JACKOWSKA and BORKOWSKA (2002) reported that a high content of nitrogen in soil was decreasing the bioavailability of some microelements to plants, and thus was reducing their content in grain. This was confirmed in the present study, where the fertilization dose of 90 kg N ha^{-1} significantly increased the contents of P, K, Ca, Fe and Zn in the grain compared to the dose of 150 kg N ha^{-1}.

The cropping system (CS) and N doses were also found to influence the content of total protein and gluten in the grain. A higher content of protein was determined in the grain harvested from the monoculture than in the grain from the crop rotation, which may be due to poorer grain filling with starch (WOŹNIAK 2007). The fertilization dose of 150 kg N ha^{-1} tended to increase the content of protein and gluten in the grain compared to the dose of 90 kg N ha^{-1}. These results are consistent with findings reported by ESER et al. (1997), JACKOWSKA and BORKOWSKA (2002), PELTONEN and VIRTANEN (1994), as well as WOŹNIAK and MAKARSKI (2012).

CONCLUSION

1. The cropping systems (CS) differentiated significantly the ash content and mineral composition of the grain. Wheat grain collected from the crop rotation (CR) was characterized by a higher content of P, Ca, Fe and Zn compared to grain harvested from the monoculture (M).

2. The applied fertilization with 90 kg N ha^{-1} increased significantly the content of P, K, Ca, Fe and Zn in the grain compared to the fertilization with 150 kg N ha^{-1}.

3. The cropping systems (CS) and nitrogen doses were also observed to differentiate the content of proteins and gluten in the grain. A higher content of protein was determined in the grain originating from M than that from CR. The content of protein and gluten increased under the influence of the fertilization dose of 150 kg N ha^{-1} compared to the dose of 90 kg N ha^{-1}.

REFERENCE

ARAUS J.L., AMARO T., CASADESUS J., ASBATI A., NACHIT M.N. 1998. *Relationship between ash content, carbon isotope discrimination and yield in drain wheat.* Aust. J. Agric. Res., 25 (6): 835-843.

CHOWDHRY M.A., RAMZAN M., ALAM K., KHALIQ I. 1995. *Correlation analysis for grain yield and quality traits in wheat.* J. Agric. Res., 33 (2): 71-74.

COOK R.J. 1981. *The influence of rotation crops on take-all decline phenomenon*. Phytopathology, 71: 189-192.

ESER D., ADAK M.S., BIESANTZ A. 1997. *Effect of fallow, winter lentil, nitrogen fertilization and different Tillage on wheat yield in the dryfarming areas of Central Anatolia.* Turk. J. Agric. For., 23: 567-576.

JACKOWSKA I., BORKOWSKA H. 2002. *The influence of nitrogen fertilization on the content of trace elements in grain of same winter wheat cultivars*. Ann. Univ. Mariae Curie Skłodowska, E 57: 87-91.

KHAN I., ZEB A. 2007. *Nutrition composition of Pakistan wheat varieties.* J. Zhejiang Univ. Sci., B 8 (8): 555-559.

KRASKA P. 2011. *Content of some elements in grain of spring wheat cv. Zebra depending on soil tillage systems and catch crops*. J. Elem., 16(3): 407-419. DOI: 10560./jelem.2011.16.3.06

MORRIS C.F., LI SHUOBI, KING G.E., ENGLE D.A., BURNS J.W., ROSS A.S. 2009. *A comprehensive genotype and environment assessment of wheat grain ash content in Oregon and Washington: analysis of variation*. Cereal Chem., 86(3): 307-312.

PARIS P., GAVAZZI C. 1972. *The ash content of durum wheat in northern Italy*. Food Sci. Technol. Abstracts Tecnica Molitoria, 23(22): 709-728.

PELTONEN J., VIRTANEN A. 1994. *Effect of nitrogen fertilization on the physicochemical and functional properties of bread wheat*. Cereal Chem., 62: 427-430.

RANHORT G.S., GERROTH J.A., GLASER B.K., LORENZ K.J. 1995. *Baking and nutritional qualities of a spelt wheat sample. Lebensm.* Wiss. Technol., 28: 118-122.

RUIBAL-MENDIETA N.L., DELACROIX D.L., MIGNOLET J.M.P., MARQUES C., ROZENBERG R., PETITJEAN G., HABIB-JIWAN J.L., MEURENS M., QEENTIN-LECLERCO J., DELZENNE N.M., LARONDELLE Y. 2005. *Spelt (Triticum aestivum ssp. spelta) as a source of breadmaking flours and bran naturally enriched in oleic acid and minerals but not phytic acid*. J. Agric. Food Chem., 53: 2751-2759.

STRUIK P.C., BONCIARELLI F. 1997. *Resource use at the cropping system level*. Eur. J. Agron., 7: 133-143.

WOŹNIAK A. 2007. *Technological parameters of winter wheat cv. Korweta in crop rotation with different wheat participation*. Acta Agrophys., 10(1): 247-255. (in Polish)

WOŹNIAK A., MAKARSKI B. 2012. *Content of minerals in grain of spring wheat cv. Koksa depending on cultivation conditions*. J. Elem., 17. (in press)

ZADOKS J.C., CHANG T.T., KONZAK C.F. 1974. *A decimal code for the growth stages of cereals.* Weed Res., 14: 415-421.

ZEB A., ALI Z., AHMAD T., ABDUMANON A. 2006. *Physicochemical characteristics of wheat varieties growing in the same and different ecological regions of Pakistan*. Pak. J. Biol. Sci., 9(9): 1823-1828.