Journal of Elementology ISSN 1644-2296

Cieślik E., Pisulewska E., Witkowicz R., Kidacka A. 2017. *Assessment of the impact of various agricultural technology levels on the content of ash and minerals in grain of selected spring barley cultivars*. J. Elem., 22(1): 195-207. DOI: 10.5601/jelem.2016.21.2.946

ORIGINAL PAPER

ASSESSMENT OF THE IMPACT OF VARIOUS AGRICULTURAL TECHNOLOGY LEVELS ON THE CONTENT OF ASH AND MINERALS IN GRAIN OF SELECTED SPRING BARLEY CULTIVARS

Ewa Cieślik[1], Elżbieta Pisulewska[2], Robert Witkowicz[2], Agnieszka Kidacka[3]

[1]Malopolska Centre of Food Monitoring
[2]Institute of Crop Production
University of Agriculture in Krakow
[3]Malopolska Plant Growing Company – HBP LLC

Abstract

The aim of the study was to evaluate the impact of different levels of agricultural technology on the content of ash and minerals in grain of 8 spring barley cultivars. A two-factor field experiment was conducted in 2010-2012, at the Institute of Cultivation and Production of Malopolska Plant Growing Company, Polanowice near Krakow. The first factor was composed of two levels of agricultural technology: A1 (10/20/50 NPK kg ha^{-1}) and A2 (additional N fertilisation in an amount of 20 kg ha^{-1} and an application of the fungicides Amistar 250 EC+ Tilt Turbo used in doses 0.6+0.6 L ha^{-1} at the shooting phase and the earing phase, respectively, as well as the growth regulator Cerone 280 SL at a dose of 0.75 L ha^{-1} applied in the late phase of shooting). The second factor consisted of 8 cultivars of spring barley: Blask, Stratus, Atico, KWS Olof, Nagradowicki, Rubinek, Skarb, and Suweren. Determinations of the ash content were performed by the gravimetric method according to PN - ISO 2171.1994; determinations of Na, K, Ca, Mg, Fe, Zn, Mn were conducted by flame atomic absorption spectrometry (F-AAS), and Cu (PN-EN 14084:2004) was measured by flameless atomic absorption spectrometry (ET-AAS) after mineralisation in a microwave sample preparation system (MarsXpress). The average ash content was significantly differentiated by the year of cultivation, being the highest in 2012. The average identified content of minerals, except iron, depended significantly on a cultivar and, except calcium and zinc, on a year of cultivation. Average concentrations of the majority of minerals (except Na, K and Fe) depended significantly on the applied cultivation technologies, although higher levels of the elements, except Ca, were assessed in barley cultivated traditionally (technological variant A1).

Keywords: *Hordeum vulgare*, macroelements, microelements, level of agricultural technology.

Ewa Cieslik Ph.D., D.Sc. Professor, Head Malopolska Centre of Food Monitoring, University of Agriculture in Kraków, Balicka Str. 122, 30-149 Kraków, Poland, e-mail: rrciesli@cyf-kr.edu.pl

INTRODUCTION

Barley (*Hordeum vulgare*) belongs to cereals which are commonly grown all over the world. It is an important type of raw material for many industries, including production of food concentrates, production of grits, brewing, distilling, feed and milling industries (Zembold, Błażewicz 2006, Kawka 2010). Owing to its chemical composition being slightly different from that of other cereals, barley is classified as plant material with functional properties (Szwajgier, Targoński 2005, Rzedzicki, Wirkijowska 2008, Zieliński et al. 2012). This cereal contains nutrients which determine its usefulness in both human nutrition and production of fortified food (Aldughpassi et al. 2012). The high content of minerals in barley, which depending on cultivars fluctuates from 2.5 to 3.1 g 100 g^{-1}, deserves particular attention. The impact of various cultivation measures should be analysed in terms of both yield quantity and quality (Pecio, Bichoński 2009, Zbroszczyk, Nowak 2009). The negative consequences of inadequate fertilisation comprise the soil's disturbed ionic equilibrium and adverse effect on the yield's chemical composition. Nitrogen fertilisation is the factor that most strongly affects the quantity of yield and its chemical composition. However, the response of barley cultivars to nitrogen treatments is highly diverse (Noworolnik, Leszczyńska 2000, Leszczyńska, Noworolnik 2005, Känkänen, Eriksson 2007, Zbroszczyk, Nowak 2009, Nogalska et al. 2011, Noworolnik 2013).

Currently, field experiments involve optimisation of tillage technologies depending on the destination of given raw material. Nitrogen fertilisation is an important element in the cultivation of spring barley because to a great extent it determines the yield quantity and its functional value (Noworolnik, Leszczyńska 2000, Bednarek, Reszka 2007). Moreover, it has been proven that adequate potassium, magnesium and phosphorus fertilisation positively influences the total content of ash, micro- and macroelements in barley grain (Woźniak, Makarski 2013).

Because cereals are an important source of minerals, whose content is also cultivar-dependent, it is essential to achieve high quality macro- and microelements in barley grain harvested for nutritional purposes through the application of a suitable technology. Therefore, it seems purposeful to test whether an extensive or intensive cultivation technology would be more appropriate for some cultivars.

The aim of the study was to assess the effect of different levels of agrotechnology (including N fertilisation and plant protection means) on the content of ash and macroelements and microelements in spring barley grain.

MATERIALS AND METHODS

Field experiment

A two-factor, three-year field experiment (split-plot) was conducted in 2010-2012, at the Experimental Station of the Malopolska Plant Growing Company in Polanowice near Krakow. One experimental factor was composed of 8 spring barley cultivars: Blask, Stratus, Altico, KWS Olof, Nagradowicki, Rubinek, Skarb and Suweren. The other factor consisted of 2 levels of cultivation: A1 (NPK 10/20/50 kg ha^{-1}) and A2 (additional N fertilisation with 20 kg ha^{-1} and the fungicides Amistar 250EC + Tilt Turbo applied at the shooting stage and at the earing phase, dosed respectively at 0.6 + 0.6 L ha^{-1}, and the growth regulator Cerowe 280SL dosed at 0.75 L ha^{-1} and applied by the end of shooting stage). The plot area for harvest was 10 m^2. Barley was cultivated in soil of quality class I, good wheat soil complex. The soil under the experimental field was degraded Chernozem developed from loess. The forecrop was winter oilseed rape in the first year of the experiment, maize in the second and beetroots in the third.

Chemical analyses

The ash content was assessed by the gravimetric method according to PN-ISO 2171.1994 standard. Determinations of sodium, potassium, calcium, magnesium, iron, zinc, and manganese concentrations were conducted using flame atomic absorption spectrometry (F-AAS), while the copper content was determined by Electrothermal Atomic Absorption Spectrometry (ET-AAS) (according to PN-EN 14084:2004), after mineralisation in a microwave sample preparation system (MarsXpress).

Statistical analysis of results

The results obtained from chemical analyses were subjected to statistical analysis using the Statistica 5.1 computer programme. Significance of differences between the tested components of barley grain depending on the cultivars, applied levels of cultivation and characteristics of the plant growing season was determined using analysis of variance.

Weather conditions

Average air temperatures and precipitation totals in the plant growing seasons between 2010 and 2012 are presented in Table 1. The highest air temperature (on average 6.05°C) was measured in 2012, whereas the highest precipitation total (940.0 mm $year^{-1}$) appeared in 2010.

Table 1

Total monthly precipitation and average monthly air temperature for the period from 1 January to 31 December 2010-2012, Malopolska Region, Poland

Lear	Precipitation (mm)			Air temperature (°C)		
	2010	2011	2012	2010	2011	2012
Month						
January	37.30	23.00	31.40	-7.50	-3.10	-2.90
February	21.50	2.700	15.70	-4.80	-5.90	-8.60
March	16.60	14.50	8.300	-0.40	-0.50	3.300
April	27.70	35.50	48.70	7.100	6.300	5.400
May	185.6	43.20	40.20	11.40	9.700	12.20
June	130.0	38.10	94.80	17.80	15.90	15.50
July	179.5	135.1	41.20	18.30	15.40	17.70
August	151.6	40.20	25.20	16.50	14.80	15.20
September	110.4	17.20	31.60	8.300	10.60	10.40
October	9.000	19.90	94.00	1.900	5.100	5.300
November	46.30	0.000	23.60	2.700	-1.20	3.30
December	24.50	20.90	17.60	-5.70	-2.60	-4.20
Total annual precipitation	940.0	390.3	472.3			
Average annual air temperature				5.500	5.400	6.100

RESULTS AND DISCUSSION

The field experiment revealed statistically significant diversification of the ash content in spring barley grain between the seasons, with the lowest ash level (1.98%) determined in 2011 (Table 2). The results might have been caused by both diverse weather conditions and different forecrops used in the individual years. Our review of the weather conditions demonstrated the lowest average air temperature (5.37°C) and the lowest precipitation total in 2011 (Table 1). In the 2012 plant growing season, beetroots were the forecrop of barley. Korbas and Mrówczyński (2012) reported that root crops (beetroots and potatoes) are very good forecrop for malting barley, whereas for forage barley legumes and oilseed rape are a better preceding crop.

The ash content was also significantly diversified by the applied technological variants, as it was demonstrated that the differentiated nitrogen fertilisation and different plant protection levels markedly affected the ash content in barley grain. However, the results did not confirm the data obtained previously by other authors (Liszewski 2008, Zbroszczyk, Nowak 2009).

Table 2

Mean content of ash, Na, K, Ca, Mg, Fe, Mn, Zn, Cu in barley grain depending on the year of cultivation, cultivar and agricultural technology

Factor	Ash	Mean content (mg kg^{-1})							
Year	(%)	Na	K	Ca	Mg	Fe	Mn	Zn	Cu
2010	2.334^{a}	19.52^{b}	3668^{b}	314.4^{a}	963.6^{b}	66.85^{a}	12.25^{a}	26.30^{a}	3.539^{a}
2011	1.984^{b}	15.85^{c}	3795^{b}	315.7^{a}	1037.4^{a}	34.13^{b}	11.40^{a}	25.33^{a}	2.473^{b}
2012	2.427^{a}	30.22^{a}	4975^{a}	348.1^{a}	992.2^{ab}	29.98^{b}	12.02^{a}	26.41^{a}	3.564^{a}
Cultivation technology									
A1	2.277^{a}	21.89^{a}	4197^{a}	317.0^{a}	1001.1^{a}	40.25^{a}	12.14^{a}	27.18^{a}	3.298^{a}
A2	2.219^{b}	21.83^{a}	4096^{a}	335.2^{a}	994.3^{b}	47.06^{a}	11.05^{b}	24.85^{b}	3.086^{b}
Cultivar									
Atico	2.269^{a}	17.89^{d}	4133^{b}	344.6^{ab}	969.1^{c}	44.78^{a}	12.15^{a}	23.81^{ef}	2.911^{b}
Blask	2.293^{a}	22.62^{b}	4488^{a}	345.3^{ab}	1027.4^{ab}	53.08^{a}	13.18^{a}	27.31^{bc}	3.721^{a}
Nagradowicki	2.206^{a}	19.26^{cd}	4072^{b}	335.3^{ab}	950.6^{c}	38.56^{a}	12.28^{a}	28.54^{b}	3.561^{a}
Olof	2.235^{a}	24.72^{ab}	4358^{a}	301.9^{ab}	983.3^{bc}	42.38^{a}	10.57^{b}	22.92^{f}	2.902^{b}
Rubinek	2.294^{a}	17.71^{d}	4034^{b}	352.4^{a}	993.4^{bc}	42.61^{a}	12.11^{a}	31.23^{a}	3.254^{ab}
Skarb	2.211^{a}	22.15^{bc}	4010^{b}	332.5^{ab}	1006^{abc}	43.59^{a}	12.20^{a}	26.29^{cd}	2.713^{b}
Stratus	2.298^{a}	27.51^{a}	4009^{b}	314.4^{ab}	1080^{a}	46.78^{a}	12.09^{a}	25.07^{de}	2.794^{b}
Suweren	2.181^{a}	23.04^{b}	4065^{b}	282.2^{b}	972.0^{bc}	37.42^{a}	10.56^{b}	22.90^{f}	3.678^{a}

a, b, c, d, e, f – mean values followed by the same letter are not significantly different ($a = 0.05$)

No diversification of the ash content was observed in grain of the analysed spring barley cultivars, because they all formed a homogenous group with a very small interval (Table 2). However, a statistical difference was noted for the source of diversification, i.e. the interaction between the cultivar and the growing season (Figure 1). Further analysis indicates that mainly the cultivar Blask was responsible for the significance of differences, since its grain in 2010 was characterised by a very high ash content (2.63%). Another cultivar, i.e. Nagradowicki, had an ash content of 2.52% in 2012. A very low content of all minerals in grain of all the cultivars was noted in 2011 (an interval between 1.89 and 2.03%).

The sodium content depended significantly on the growing season and cultivar. The lowest average sodium content (15.85 mg kg^{-1}) was found in 2011, and the highest one (30.22 mg kg^{-1}) occurred in 2012. Of the 8 barley cultivars, cv. Rubinek was characterised by the lowest level of Na (an average of 17.71 mg kg^{-1}), while cv. Stratus had the highest Na concentration in grain (an average of 27.51 mg kg^{-1}) – Table 2. The cultivar factor affected the sodium content in grain. The cultivars Olof and Stratus may be counted among barley cultivars with the highest sodium concentrations. The subsequent group with a slightly lower content of this element was formed by the cultivars Blask, Skarb and Suweren. The lowest sodium concentration, below 20 mg kg^{-1}, was determined in the grain of the cultivars Atico, Nagradowicki and Rubinek. The variation in the grain sodium content resulted also from the cultivar x year interaction. Sodium concentrations in grain of all the cultivars differed in years (Figure 1). Moreover, the sodium content in grain of the cultivars Olof, Rubinek and Suweren in 2011 differed from the concentrations observed in the other two years. Barley grain of all the cultivars harvested in 2012 contained markedly more sodium than in 2010 and 2011.

The potassium content in barley grain depended significantly on the plant growing season and the cultivar (Table 2). Significant differences in the content of potassium between the studied cultivars and years of cultivation were also reported by Zbroszczyk and Nowak (2009). The highest average potassium content (4975 mg kg^{-1}) was found in the 2012 season. Significantly higher levels of potassium were shown in studies of Shar et al. (2007), namely 7892.7 mg kg^{-1} and 7028 mg kg^{-1}, depending on potassium fertilisation. This could be due to a higher level of potassium fertilisation (45%) in the cited field experiment. The highest potassium content was determined in grain of two cultivars: Blask (an average of 4488 mg kg^{-1}) and Olof (4358 mg kg^{-1}). The other cultivars formed a homogenous group with a statistically lower content of this element in grain. The potassium concentration in grain was also modified by two interactions: the cultivar x year and the cultivar x technological variant. As for the first interaction, high potassium concentrations were noted in the cultivars Blask and Olof cultivars in 2010 and very high potassium content was determined in grain of all the cultivars in 2012 (from 4795 to 5221 mg kg^{-1}) – Figure 1. The statistical effect of the cultivar x

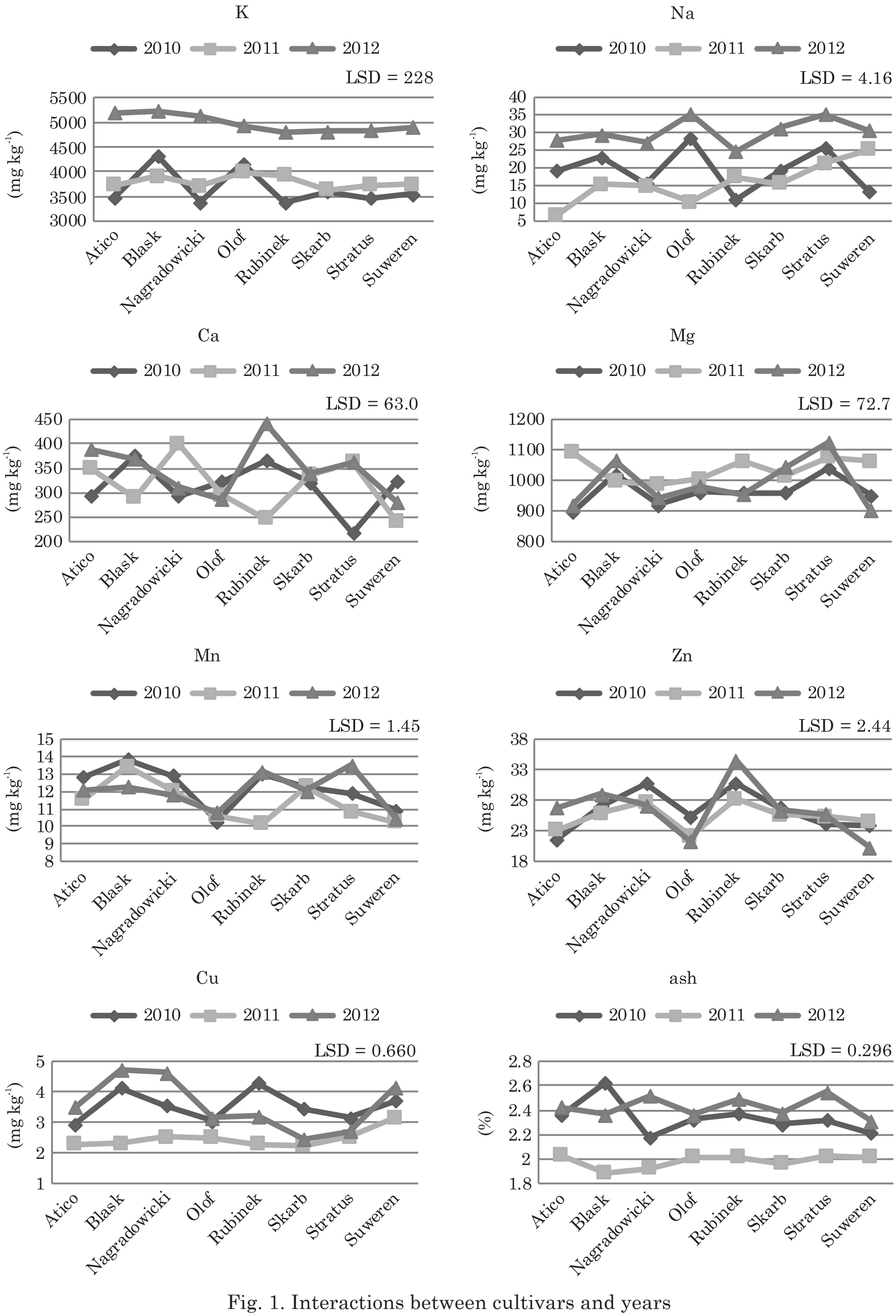

Fig. 1. Interactions between cultivars and years

technological variant interaction was due to cv. Skarb, which was the only cultivar that accumulated a higher potassium content in grain in the extensive technological variant (Figure 2).

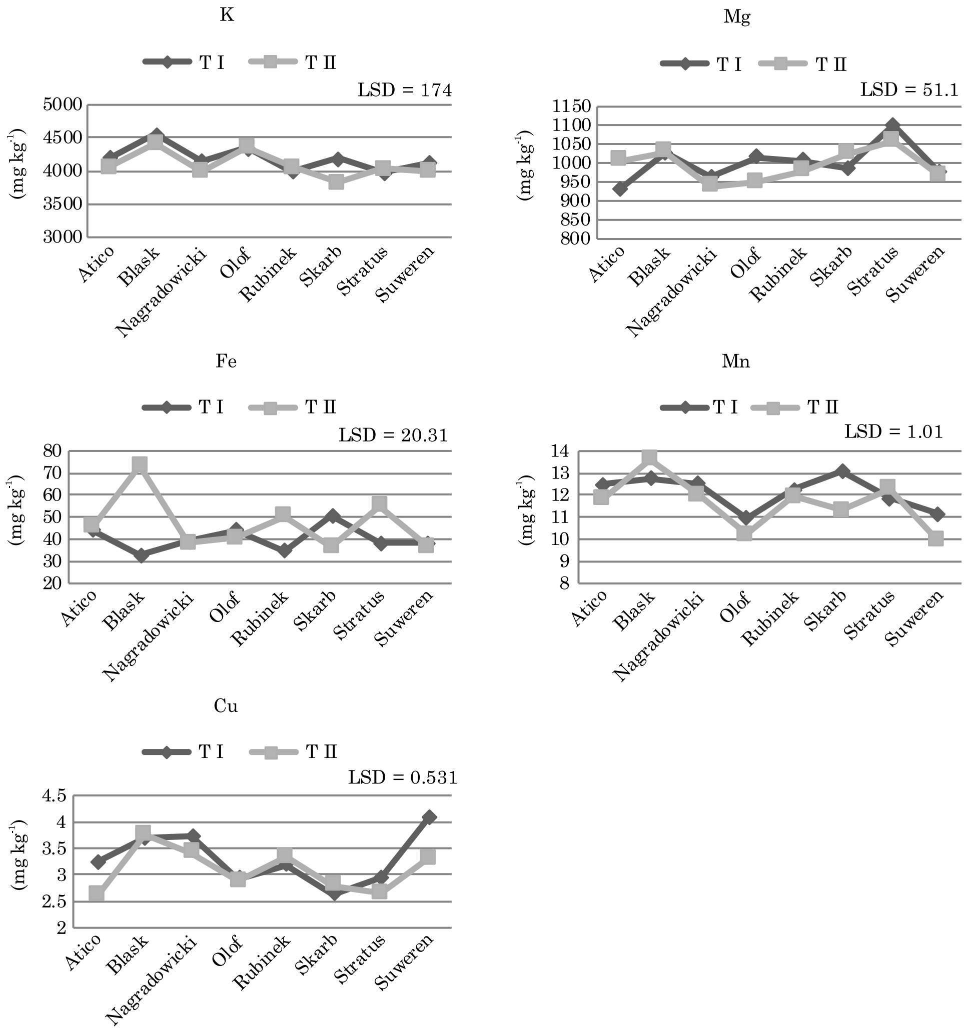

Fig. 2. Interactions between cultivars and technology variants

It was found that the calcium content in spring barley grain was not markedly diversified, either between the applied technological variants or between the analysed years (Table 2). Among the analysed cultivars, the highest average calcium content (352.2 mg kg^{-1}), occurred in cv. Rubinek (group a), while the lowest one (on average 282.2 mg kg^{-1}) was detected in cv. Suweren (group c). The other cultivars formed one homogenous group, which did not differ from the ones mentioned above. A higher average content of calcium (393.0 mg kg^{-1}) was determined in spring barley grain in the research of Ciołek et al. (2012), whereas a much higher content (831.53 mg kg^{-1}) was found in 5 Pakistani cultivars (Shar et al. 2007). The calcium concentrations in grain also remained under the influence of the cultivar x year interaction. For all the cultivars, the years with statistically different concentrations of this element in grain may be indicated. Statistical differentiation of this source of changeability was mainly due to calcium concentrations in the grain of the cultivars Blask, Nagradowicki, Rubinek grown in 2011 and the cultivar Stratus harvested in 2012 (Figure 1).

The magnesium content in spring barley grain significantly depended on the plant growing season, applied technological variants and cultivars (Table 2). A significantly higher magnesium content (1037.4 mg kg^{-1}) was assessed in the growing season of 2011 than in 2010 and 2012. The spring barley cultivars studied by Ciołek et al. (2012) had lower amounts of magnesium (848 mg kg^{-1}). Barley grain from A2 plots was characterised by a significantly lower average content of magnesium (994.3 mg kg^{-1}). The cultivar Stratus was distinguished by the highest content of magnesium (on average 1080 mg kg^{-1}). The variance analysis showed that also cv. Blask and Skarb belonged to the group of cultivars with the highest Mg content. The other cultivars had markedly lower magnesium concentrations in grain, although cv. Skarb also fell to this category. The results differed from the ones reported by other authors, where the magnesium content was not significantly diversified by the analysed factors (cultivar, levels of plant protection) (Zbroszczyk, Nowak 2009). The magnesium content in grain was also conditioned by the cultivar x year, the cultivar x technological variant and the year x technological variant interactions. As for the first interaction mentioned above, to a large extent its statistical significance resulted from the calcium concentration in grain of the cultivars Atico, Rubinek and Suweren harvested in 2011, which – in the context of previously discussed concentrations of other elements – confirms the instability of barley grain composition originating from that year (Figure 1). Magnesium concentrations in grain from the tested cultivars were also modified by the cultivation intensity. Particularly, the cultivars Atico and Olof provide evidence for this effect, although higher magnesium concentrations were related to the different cultivation intensity levels. Regarding cv. Atico, a higher calcium concentration (1006.2 mg kg^{-1}) was recorded in the intensive technology variant, whereas cv. Olof accumulated more calcium (1016.1 mg kg^{-1}) in extensive cultivation (Figure 2). It may also be noticed that the calcium content in grain from the individual technological variants depended on a year. The calcium content in barley grain from the first technological variant did not differ between the years, whereas in intensive cultivation statistically different calcium content in grain was obtained each year (Figure 3).

The iron content assessed in spring barley grain was diversified only by the plant growing season (Table 2). The highest average iron content (66.85 mg kg^{-1}) was determined in the 2010 season. The relationship between the iron concentration and the plant growing season (higher precipitation)

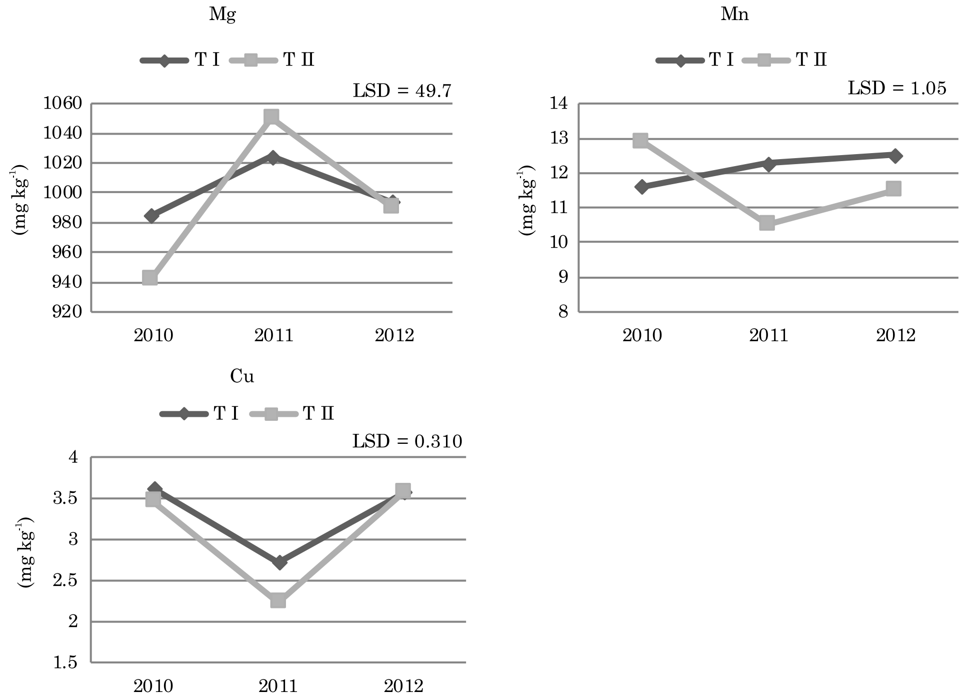

Fig. 3. Interactions between the years and technology variants

was observed in the research conducted by MALEKI et al. (2011). The iron content in barley grain was also shaped by the cultivar and technological variant interaction. This source of changeability owes its significance to cv. Blask, which was the only cultivar that responded to the intensification of production by a nearly doubled iron content (Figure 2).

The manganese content in spring barley grain depended significantly on the growing technology and cultivar (Table 2). The research revealed that the applied levels of agrotechnology significantly affected the manganese content in barley, although the grain of traditionally cultivated barley (variant A) had more manganese (on average 12.14 mg kg^{-1}). Among the analysed cultivars, Suweren and Olof revealed the lowest average manganese content (10.56 and 10.57 mg kg^{-1}, respectively). Much higher amounts of manganese in Pakistani barley cultivars were determined by SHAR et al. (2007) and in barley grown in a field experiment conducted by MALEKI et al. (2011), where on average 20.96 mg kg^{-1} manganese was found in grain. Manganese, like magnesium, was affected by three interactions: the cultivar x year, the cultivar x technological variant and the year x technological variant. With respect to the first of the above mentioned interactions, all cultivars except Olof, Skarb and Suweren accumulated variable manganese concentrations in grain (Figure 1). The technological variant diversified concentrations of this element in the grain from cv. Skarb and Suweren, however the grain from the extensive cultivation level had a higher content of manganese (Figure 2). The year and cultivation level interaction allows us to explore differences between both years and technologies. The distinctiveness of the year 2010 becomes evident because higher magnesium content accumulated in the grain from the intensive technological variant (Figure 3).

The zinc concentrations in spring barley grain were statistically significantly diversified between both the applied technological variants and the compared cultivars (Table 2). The barley grain from objects A2 (where additional nitrogen fertilisation and plant protection was applied) was characterised by a significantly lower average zinc content (24.85 mg kg^{-1}). The average zinc content in grain of the analysed barley cultivars fluctuated from 22.90 mg kg^{-1} for cv. Suweren to 31.23 mg kg^{-1} for cv. Rubinek. Higher zinc concentrations were determined in Pakistani barley cultivars – 24.82-39.19 mg kg^{-1} (Shar et al. 2007), and in the field experiment by Maleki et al. (2011). Variability of the zinc content in grain also resulted from the interaction of the cultivar and technological variant (Figure 1). Apart from the cultivars Stratus and Suweren, the content of this element in the other cultivars was diversified between the years. The cultivar Rubinek presented the greatest differentiation of the zinc content in years (28.27-34.62 mg kg^{-1}).

The copper concentrations in spring barley grain were significantly diversified by the year, technology variant and cultivar (Table 2). Significantly higher copper content was determined in spring barley grain cultivated in 2012 and 2010 than in 2011 (3.56 mg kg^{-1}). Barley cultivated in technological variant A2 contained significantly less copper (3.086 mg kg^{-1}). Among the studied cultivars, the highest average copper content (3.72 mg kg^{-1}) was detected in cv. Blask. Analysis of variance showed that the group of cultivars with the highest Cu content in grain also comprised the cultivars Suweren, Rubinek and Nagradowicki. The average copper concentration (3.67 mg kg^{-1}) in barley grain reported by Ciołek et al. (2012) generally fell within the range determined in our experiment. Much higher amounts of copper (6.29-8.12 mg kg^{-1}) were shown in Pakistani barley cultivars by Shar et al. (2007). The copper concentrations in barley grain resulted from the cultivar x year, cultivar x technological variant and the year x technological variant interactions. Regarding the first of the above interactions, the cultivars Olof and Stratus were an exception in that they did not confirm copper concentration diversification in grain due to the cultivar x year dependence. The other cultivars were characterised by considerable diversification of the content in years, but accumulated the lowest amounts of this element in 2011 (Figure 1). Only two cultivars, cv. Atico and Suweren, responded to a change of cultivation intensity by presenting different grain copper concentrations. Both cultivars accumulated markedly less copper in grain when cultivated in the extensive variant (Figure 2). A decline in the copper concentration was also observed in response to production intensification, but only in 2011. In the other years, the level of the analysed technological variants did not diversify the copper content in barley grain (Figure 3).

CONCLUSIONS

1. The ash content in spring barley grain was significantly diversified between the years and applied variants of cultivation technologies. Less ash in grain was determined in 2011 thaan in 2012 or 2010, because the plant growing season of 2011was dry and cold.

2. The average content of the elements, except calcium and zinc, depended significantly on the plant growing year.

3. Statistical analysis of the results revealed that theaverage content of the minerals, except iron, depended markedly on the cultivars. The cultivar Blask distinguished itself by its high content of minerals, including K, Mg, Fe, Mn and Cu.

4. The average content of most of the minerals (except Na, K and Fe) depended significantly on thee applied growing technologies. Higher levels of the elements, except Ca, were determined in barley cultivated traditionally (technological variant A1).

5. The interactions between the barley cultivars and the growing season were demonstrated for all the minerals except iron. In contrast, the interaction between the barley cultivars and technological variants was confirmed for five elements (K, Mg, Fe, Mn, Cu). The interaction between the year and cultivation variant was significant for Mg, Mn and Cu.

REFERENCES

Aldughpassi A., Abdel-Aal E.M., Wolever T.M.S. 2012. *Barley cultivar, kernel composition, and processing affect the Glycemic Index.* J Nutr., 142(9): 1666-71. DOI: 10.3945/jn.112.161372

Bednarek W., Reszka R. 2007. *The influence of liming and fertilization with various nitrogen forms on yielding and utilization of phosphorus by spring barley.* Ann. UMCS, Sect. E, Agric., 62(1): 69-76. (in Polish)

Ciołek A., Makarska E., Wesołowski M., Cierpiała R. 2012. *Content of selected nutrients in wheat, barley and oat grain from organic and conventional farming.* J Elem, 17: 181-189.

Kawka A. 2010. *Present trends in bakery production – Use of oats and barley as non-bread cereals.* Żywność. Nauka. Technologia. Jakość. / Food. Science. Technology. Quality, 3(70): 25-43. (in Polish)

Känkänen H., Eriksson Ch. 2007. *Effects of undersown crops on soil mineral N and grain yield of spring barley.* Eur J Argon, 27(1): 25-34. DOI: 10.1016/j.eja.2007/01/010

Korbas M., Mrówczyński M. (ed). 2012. *Methodology of integrated pest control for winter and spring barley producers.* Monograph. Institute of Plant Protection, National Research Institute, 4-13. (in Polish)

Leszczyńska D., Noworolnik K. 2005. *Comparison of the response of mulit-row and two-row winter barley cultivars to the level of nitrogen fertilization and sowing date.* Biul. Inst. Hod. Aklim. Rośl., 237/238: 39-49. (in Polish)

Liszewski M. 2008. *Response of two forms of fodder spring barley to different cultivation technologies.* Zesz. Nauk. UP we Wrocławiu, Rozprawy 565. (in Polish)

Maleki F.S., Chaichi M.R., Mazaheri D., Tavakkol Afshari R., Savaghebi Gh. 2011. *Barley grain mineral analysis as affected by different fertilizing systems and by drought stress.* J Agric Sci Technol, 13: 315-326.

Nogalska A., Czapla J., Skwierawska M. 2011. *The effect of multi-component fertilizers on spring barley field, the content and uptake of macronutrients.* Pol J Natur Sci., 26(2): 89-97, http://dlibra.bg.uwm.edu.pl/dlibra/docmetadata?id=1478&from=publication&tab=1.

Noworolnik K. 2013. *Effect of nitrogen fertilization on yielding and grain quality of spring barley cultivars.* Fragm Agron, 30(3): 123-131. (in Polish) http://www.up.poznan.pl/pta/fragmenta-agronomica-vol-30-no-3-2013.html

Noworolnik K., Leszczyńska D. 2000. *The response of spring barley varieties to the level of nitrogen fertilization.* Biul. Inst. Hod. Aklim. Rośl., 214: 163-166. (in Polish)

Pecio A., Bichoński A. 2009. *Nitrogen fertilization and fungicide application as the elements of spring barley production.* Biul. Inst. Hod. Aklim. Rośl., 252: 201-213. (in Polish)

Rzedzicki Z., Wirkijowska A. 2008. *Chemical composition profile of some selected barley products with the fractional composition of dietary fibre taken into consideration.* Żywność. Nauka. Technologia. Jakość. / Food. Science. Technology. Quality, 1(56): 52-64. (in Polish) http://www.pttz.org/zyw/

Shar G.Q., Shar L.A., Kazi T.G., Afridi M.B., Arain M.B., Jamali M.K. 2007. *Multielement analysis of Pakistani barley (Hordeum vulgare* L.*) varieties by Flame Atomic Absorption Spectrometry.* J. Res. Sci. B. Z. Univ., 18: 2:67-77.

Szwajgier D., Targoński Z. 2005. *Arabinoxylans from malt as a source of natural antioxidant ferulic acid and dietary fiber in beer.* Żywność. Nauka. Technologia. Jakość. / Food. Science. Technology. Quality, 4(45): 27-41. (in Polish)

Woźniak A., Makarski B. 2013. *Content of minerals, total protein and wet gluten in grain of spring wheat depending on cropping systems.* J. Elem., 18(2): 297-305. DOI: 10.5601/jelem.2013.18.2.09

Zbroszczyk T., Nowak W. 2009. *Effect of the protection level and nitrogen fertilization on yielding and chemical composition of the grain of several varieties of fodder spring barley.* Part II. *Chemical composition.* Biul. Inst. Hod. Aklim. Rośl., 251: 145-152. (in Polish)

Zembold A., Błażewicz J. 2006. *The grain of naked and hulled barley as unmalted raw material in brewing industry.* Żywność. Nauka. Technologia. Jakość. / Food. Science. Technology. Quality, 3(48): 35-50. (in Polish)

Zieliński H., Achremowicz B., Przygodzka M. 2012. *Antioxidants of cereal grains.* Żywność. Nauka. Technologia. Jakość. / Food. Science. Technology. Quality, 1(80): 5-26. (in Polish)