J. Elem. s. 79–90 DOI: 10.5601/jelem.2013.18.1.06

EFFECT OF CHEMICAL CROP PROTECTION ON THE CONTENT OF SOME ELEMENTS IN GRAIN OF SPELT WHEAT (*TRITICUM AESTIVUM* SSP. *SPELTA*)

Piotr Kraska, Sylwia Andruszczak, Ewa Kwiecińska-Poppe, Edward Pałys

Chair of Agricultural Ecology
University of Life Sciences in Lublin

Abstract

The aim of the present study was to evaluate the effect of chemical crop protection on the content of N, P, K, Mg, Zn, Cu, Mn, and Fe in grain of 8 spelt wheat cultivars (Franckenkorn, Badengold, Schwabenspelz, Oberkulmer Rotkorn, Ostro, Ceralio, Schwabenkorn, and Spelt I.N.Z.). Chemical protection involved application of a fungicide, two herbicides and a retardant. No plant protection agents were used in the control treatment. The above spelt cultivars were grown in a monoculture on medium heavy mixed rendzina soil. The study was carried out in 2009-2011, at the Bezek Experimental Farm, which belongs to the University of Life Sciences in Lublin.

Among the spelt wheat cultivars compared, grain of cv. Ostro was characterized by the highest content of nitrogen, phosphorus and manganese, whereas grain of cv. Franckenkorn contained the largest amounts of potassium and magnesium. The highest amount of zinc was found in grain of cv. Oberkulmer Rotkorn and that of copper – in grain of cv. Spelt I.N.Z., while grain of cv. Schwabenkorn was found to be the richest in iron. Irrespective of the cultivar, chemical plant protection significantly increased the copper content in spelt grain and simultaneously decreased the magnesium content. The content of N, Mg, Zn, Cu, and Mn in grain decreased in the successive years of the study.

Key words: spelt wheat, cultivars, chemical protection, grain chemical composition.

dr inż. Piotr Kraska, Chair of Agricultural Ecology, University of Life Sciences in Lublin, Akademicka 13 Street, 20-950 Lublin, Poland, e-mail: piotr.kraska@up.lublin.pl

WPŁYW CHEMICZNEJ OCHRONY ŁANU NA ZAWARTOŚĆ WYBRANYCH PIERWIASTKÓW W ZIARNIE PSZENICY ORKISZ (*TRITICUM AESTIVUM* SSP. *SPELTA*)

Abstrakt

Celem badań była ocena wpływu chemicznej ochrony łanu na zawartości N, P, K, Mg, Zn, Cu, Mn i Fe w ziarnie 8 odmian pszenicy orkisz (Franckenkorn, Badengold, Schwabenspelz, Oberkulmer Rotkorn, Ostro, Ceralio, Schwabenkorn, Spelt I.N.Z.). Ochrona chemiczna polegała na zastosowaniu fungicydu, dwóch herbicydów oraz retardanta. W obiekcie kontrolnym nie stosowano żadnych środków ochrony roślin. Wymienione odmiany orkiszu uprawiano po sobie na średnio ciężkiej rędzinie mieszanej. Badania przeprowadzono w latach 2009-2011 w Gospodarstwie Doświadczalnym Bezek należącym do Uniwersytetu Przyrodniczego w Lublinie.

Spośród porównywanych odmian pszenicy orkisz największą zawartość azotu, fosforu i manganu stwierdzono w ziarnie odmiany Ostro, natomiast najwięcej potasu i magnezu zawierało ziarno odmiany Franckenkorn. Największą zawartość cynku stwierdzono w ziarnie odmiany Oberkulmer Rotkorn, miedzi – w ziarnie odmiany Spelt I.N.Z., zaś żelaza w ziarnie odmiany Schwabenkorn. Niezależnie od odmiany, chemiczna ochrona roślin istotnie wpłynęła na zwiększenie zawartości miedzi w ziarnie orkiszu i jednocześnie zmniejszenie zawartości magnezu. Zawartość N, Mg, Zn, Cu oraz Mn w ziarnie zmniejszała się w kolejnych latach badań.

Słowa kluczowe: pszenica orkisz, odmiany, ochrona chemiczna, skład chemiczny ziarna.

INTRODUCTION

The interest in spelt cultivation is growing continually. It is stimulated by the introduction of eco-friendly technologies and by consumers' growing interest in new products (SULEWSKA 2004ab, TYBURSKI, ŻUK-GOŁASZEWSKA 2005, SULEWSKA et al. 2008). Spelt is more resistant to diseases and environmental stresses than common wheat (BAUMGÄRTEL-BLASCHKE 1992). On the other hand, it has traits typical of wild wheat varieties, such as a brittle rachis, poor threshing and a significant height, which makes it more vulnerable to lodging. As a result, it is difficult to grow spelt wheat on a large scale (CAMPBEL 1997). Owing to the enclosing glumes, spelt grain does not need to be dressed before sowing (WINZELER, RÜEGGER 1990). Hence, it can be successfully grown at both conventional and ecological farms (PAŁYS, KURASZKIEWICZ, 2003, ANDRUSZCZAK et al. 2011, KWIECIŃSKA-POPPE et al. 2011).

For consumers and with respect to the nutritional value of raw material, the content of elements in quality wheat grain is an important trait (STANISŁAWSKA-GLUBIAK et al. 1996, CZUBA, 2000, GEMBARZEWSKI 2000, KOCOŃ 2005, STANISŁAWSKA-GLUBIAK, KORZENIOWSKA 2007, KORZENIOWSKA 2008). Spelt wheat is characterized by better biochemical composition of grain compared to common wheat cultivars (CAMPBELL 1997, SULEWSKA et al. 2008). Generally, it contains more gluten-rich protein and also has more zinc, copper and selenium

(BAUMGÄRTEL-BLASCHKE 1992, GRELA 1996, RACHOŃ, SZUMIŁO 2009). The linoleic acid is predominant in the composition of fatty acids in spelt grain. This grain contains more vitamins from the groups A, E and D. The largest amount of gamma- and alpha-tocopherols is found in the composition of vitamin E and their content is higher than in wheat grain (TYBURSKI, ŻUK-GOŁASZEWSKA 2005). Moreover, spelt bread is often tolerated by people who have been found to be allergic to wheat products (CAMPBELL 1997). Spelt grain gives a guarantee that grain of high vigour and high nutritional value is obtained (TYBURSKI, ŻUK-GOŁASZEWSKA 2005).

The application of chemical plant protection agents, in particular herbicides, in cereal growing technology has become an indispensable element in modern agriculture. At the same time, this creates a need to control their effects on yield quality, since these compounds may affect plant metabolic processes and cause changes in grain quality (NARKIEWICZ-JODKO et al. 2002, MULARCZYK et al. 2010).

The aim of the present study was to evaluate the effect of chemical crop protection on the content of some macro- and micronutrients in grain of eight spelt wheat cultivars.

MATERIAL AND METHODS

In 2009-2011, a field study was conducted at the Bezek Experimental Farm near Chełm (N: 51° 19; E: 23° 25), which belongs to the Department of Agricultural Ecology of the University of Life Sciences in Lublin. The experiment was established on medium heavy mixed rendzina soil originating from chalk rock, with the grain-size distribution of medium silty loam. This soil is classified as soil quality class IIIb and defective wheat complex. It was characterized by alkaline pH (pH in 1mol KCl – 7.35), a high content of phosphorus (117.8 mg kg^{-1} of soil) and potassium (242.4 mg kg^{-1} of soil) as well as a very low magnesium content (19.0 mg kg^{-1} of soil). The organic carbon content was 24.7 g kg^{-1}. The total rainfall from April to August in 2009, 2010, and 2011 was higher than the long-term average. In particular, the year 2010 was characterized by high rainfall during this period. Worth noticing is very high total rainfall in June 2009, July and August 2010 as well as in July 2011. The mean air temperatures in all the years were higher than the long-term average (Table 1).

The experiment evaluated the effect of chemical crop protection on the content of some macro- and micronutrients in grain of eight spelt wheat cultivars (Franckenkorn, Badengold, Schwabenspelz, Oberkulmer Rotkorn, Ostro, Ceralio, Schwabenkorn, and Spelt I.N.Z.) grown in the same plots year after year. Common wheat was the forecrop for the experiment, while spelt wheat was grown in a monoculture. Tillage was done in accordance

Table 1

Rainfall and air temperatures in April-August in 2009-2011 as compared to the long-term means (1974-2010) according to the Meteorological Station at Bezek

Years	Months					Total
	Apr	May	Jun	Jul	Aug	
	rainfall (mm)					
2009	10.1	86.8	180.5	50.8	46.9	375.1
2010	20.4	72.4	94.4	156.0	141.9	485.1
2011	30.6	40.8	88.5	178.9	38.5	377.3
Mean for 1974-2010	37.9	57.4	76.9	81.6	69.8	323.6
	temperature (^{o}C)					mean
2009	11.2	13.0	16.2	19.9	18.1	15.7
2010	9.0	14.5	17.6	20.8	19.7	16.3
2011	9.9	14.2	18.2	18.8	18.4	15.9
Mean for 1974-2010	7.8	13.5	16.3	18.2	17.6	14.7

with the generally accepted agronomic recommendations. After the harvest of the forecrop, skimming and harrowing were done. Pre-sowing ploughing with harrowing was performed about 3 weeks before spelt sowing. Harrowing was also carried out immediately before sowing. Spelt spikelets were sown in the middle of October at a rate of 350 kg per hectare.

The experiment was set up in a split-plot design with 3 replications and the harvest plot area was 8 m^2. Mineral fertilization was as follows (in kg of nutrient per hectare): N 60 (20+40); P 26.2; K 83. Phosphorus fertilizers in the form of granulated triple superphosphate, potassium fertilizers in the form of 60% potassium salt, and 20 kg N ha^{-1} in the form of ammonium nitrate were applied before spelt sowing. A dose of 40 kg N ha^{-1} was incorporated in the spring at the stem elongation stage (BBCH 32-34).

Chemical plant protection included the application of the following agents: Alert 375 SC (the content of active substances: flusilazole 125 g l^{-1}, a compound from the triazole group; carbendazim 250 g l^{-1}, a compound from the benzimidazole group) applied against diseases at the stem elongation stage (BBCH 32-34) at a rate of 1 l ha^{-1}; Mustang 306 SE (the content of active substances: florasulam 6.25 g l^{-1}, a compound from the triazolopyrimidine group; 2,4-D EHE 300 g l^{-1}, a compound from the phenoxy acid group) used to control dicotyledonous weeds, as well as Attribut 70 WG (the content of active substances: propoxycarbazone 70%, a compound from the sulfonyl-amino-carbonyl-triazolinone group; methyl ester of 2-benzoic acid sodium salt) against monocotyledonous weeds applied at the tillering stage (BBCH 24-29) at rates of 0.4 l ha^{-1} and 60 g ha^{-1}, respectively; Stabilan 750 SL (the active substance chlormequat chloride 750 g l^{-1}) applied at the stem elongation stage (BBCH 32-34) at a rate of 2 l ha^{-1}. Plots where no chemical plant protection agents were used served as the control treatment.

The elements were determined based on collective samples from three replications using the following methods: total N by Kjeldahl method; P by colorimetry; K by flame photometry; Mg, Cu, Zn, Mn, Fe by atomic absorption spectrometry (AAS). The results were statistically analysed by analysis of variance for three-way classification and least significant differences were calculated using Tukey's confidence half-intervals with a 5% error risk. The calculations were performed using ARStat software developed by the Computing Centre of the University of Life Sciences in Lublin.

RESULTS AND DISCUSSION

The nitrogen content in grain of cv. Badengold was significantly lower than in grain of the cultivars Schwabenspelz, Franckenkorn, Ceralio, Oberkulmer Rotkorn, Schwabenkorn, and Ostro. At the same time, grain of the cultivars Schwabenkorn and Ostro was distinguished by a higher content of nitrogen compared to cv. Spelt I.N.Z. (Table 2). In the study of Pałys and Łabuda (1997), the lowest N content was found in grain of the spelt wheat cultivar Bauländer Spelz (16.52 g kg^{-1}), whereas this content was the highest in grain of cv. Loge (22.75 g kg^{-1}). Stanisławska-Głubiak and Korzeniowska (2011) determined the N content in grain of winter wheat cultivars at a level ranging from 18.5 to 21.1 g kg^{-1}, thus being slightly lower than in the case of the spelt cultivars under evaluation.

Grain of the spelt cultivars Franckenkorn and Ostro was found to have a significantly higher P content in comparison to the cultivars Badengold, Schwabenspelz, and Spelt I.N.Z (Table 2). Pałys and Łabuda (1997) found a higher phosphorus content (from 7.36 to 8.79 g kg^{-1}) in spelt grain. On the other hand, the content of this element in spelt grain determined by Grela (1996), i.e. from 4.16 to 4.39 g kg^{-1}, and by Rachoń and Szumiło (2009), i.e. from 4.20 to 4.60 g kg^{-1}, was similar to the results obtained in the present experiment. Gembarzewski et al. (1995) determined the average P content in winter wheat grain at a level of 3.8 to 4.3 g kg^{-1}. In turn, Kraska (2011) found the P content in grain to be from 3.69 to 5.88 g kg^{-1}.

Grain of the cultivar Franckenkorn was characterized by a significantly higher K content in comparison with cv. Oberkulmer Rotkorn and, at the same time, by a higher Mg content than cv. Badengold. In the studies of Grela (1996) and of Rachoń and Szumiło (2009), the K content in spelt grain was higher (4.39-5.52 g kg^{-1} and 4.30-4.40 g kg^{-1}, respectively,), while the magnesium content was similar to that obtained in the present experiment. Kraska (2007) as well as Kraska and Pałys (2008, 2009) found a distinctly

Table 2

Content of some macronutrients in spelt grain depending on cultivars and different protection levels
(means for 2009-2011)

Specification		Cultivars								Mean
Element	protection level	Franken-korn	Badengold	Schwaben-spelz	Oberkulmer Rotkorn	Ostro	Ceralio	Schwaben-korn	Spelt I.N.Z.	
N (g kg^{-1} d.m.)	without protection	22.73	21.07	23.70	24.53	25.00	23.17	24.53	23.23	23.50
	with protection	23.67	21.53	22.30	24.50	26.13	24.40	24.70	22.63	23.73
	mean	23.20	21.30	23.00	24.52	25.57	23.78	24.62	22.93	-
LSD p = 0.05		cultivar 1.686; protection level *ns								
P (g kg^{-1} d.m.)	without protection	4.66	4.38	4.48	4.51	4.79	4.46	4.46	4.43	4.52
	with protection	4.77	4.22	4.17	4.57	4.82	4.49	4.58	4.30	4.49
	mean	4.72	4.30	4.33	4.54	4.81	4.48	4.52	4.37	-
LSD p = 0.05		cultivar 0.346; protection level *ns								
K (g kg^{-1} d.m.)	without protection	3.60	3.55	3.64	3.19	3.48	3.59	3.50	3.42	3.50
	with protection	3.73	3.59	3.41	3.17	3.51	3.46	3.58	3.34	3.47
	mean	3.66	3.57	3.53	3.18	3.50	3.52	3.54	3.38	-
LSD p = 0.05		cultivar 0.434; protection level *ns								
Mg (g kg^{-1} d.m.)	without protection	1.66	1.53	1.65	1.55	1.62	1.56	1.60	1.63	1.60
	with protection	1.71	1.40	1.53	1.58	1.60	1.48	1.49	1.46	1.53
	mean	1.69	1.46	1.59	1.57	1.61	1.52	1.55	1.54	-
LSD p = 0.05		cultivar 0.196; protection level 0.059								

*ns – difference not significant

lower content of N, P, and Mg in wheat and winter triticale grain than that determined in the spelt cultivars under evaluation. In another study (KRASKA 2011), the K content in spring wheat grain (4.02-4.16 g kg^{-1}) was higher, while the magnesium content was lower (1.03-1.18 g kg^{-1}) than in grain of the spelt cultivars compared in our experiment.

The cultivar Oberkulmer Rotkorn was distinguished by a significantly higher zinc content in grain in comparison with the cultivars Badengold, Franckenkorn, Ceralio, and Schwabenspelz (Table 3). In the study of PAŁYS and ŁABUDA (1997), the Zn content in grain of the evaluated spelt wheat cultivars was much lower and ranged from 16.0 to 25.0 mg kg^{-1}. In the present study, the zinc content in grain was in the range from 38.07 to 47.58 mg kg^{-1}, while in the study of RACHOŃ and SZUMIŁO (2009) it ranged from 31.5 to 37.0 mg kg^{-1}. GRELA (1996) found a distinctly higher content of zinc only in grain of cv. Bauländer Spelz (51.30 mg kg^{-1}).

The Cu content in grain of the cultivars Oberkulmer Rotkorn, Franckenkorn and Spelt I.N.Z was significantly higher than in grain of cv. Badengold (Table 3). GRELA (1996) as well as PAŁYS and ŁABUDA (1997) showed a higher Cu content in spelt grain (10.97 mg kg^{-1} and 8.0 mg kg^{-1}, respectively), whereas RACHOŃ and SZUMIŁO (2009) found markedly less Cu (2.85--2.99 mg kg^{-1}). KORZENIOWSKA and STANISŁAWSKA-GLUBIAK (2011) determined the average Cu content in 10 winter wheat cultivars at a level of 2.42-2.59 mg kg^{-1}. GEMBARZEWSKI et al. (1995) report that Polish wheats contain on average 3.1-3.4 mg of copper in 1 kg of grain, thus much less than in the present study. In turn, in the research of KRASKA (2011) the Cu content in spring wheat grain was from 3.06 mg kg^{-1} to 5.68 mg kg^{-1}, depending on the conditions in a particular year.

The highest Mn content was found in grain of the cultivar Ostro, whereas the lowest one in grain of cv. Badengold (Table 3). The Mn content determined in spelt grain by GRELA (1996) ranging from 38.30 mg kg^{-1} (cv. Rouquin) to 64.20 mg kg^{-1} (cv. Bauländer Spelz) was higher, while that obtained by PAŁYS and ŁABUDA (1997) was clearly lower than estimated in the present study. In turn, RACHOŃ and SZUMIŁO (2009) determined the Mn content in grain of the tested spelt wheat lines at a level ranging from 37.0 to 41.6 mg kg^{-1}. The manganese content in grain was similar to that given by GEMBARZEWSKI et al. (1995) for winter wheat grain (35-47 mg kg^{-1}) and markedly higher, except for cv. Badengold, than the one obtained on the same soil by KRASKA (2011) in spring wheat grain (18.38-28.20 mg kg^{-1}).

The genetic factor did not differentiate significantly the Fe content in spelt grain. A trend was only observed towards a lower Fe content in grain of cv. Badengold compared to grain of the other cultivars (Table 3). RACHOŃ and SZUMIŁO (2009) estimated the Fe content in spelt grain at 32.2-33.9 mg kg^{-1}, thus at a similar level to that obtained for cv. Badengold. The highest Fe content determined by PAŁYS and ŁABUDA (1997) in grain of cv. Bauländer Spelz (32 mg kg^{-1}) was lower than the one found in the spelt cultivars

Table 3

Content of some micronutrients in spelt grain depending on cultivars and different protection levels (means for 2009-2011)

Specification		Cultivars								Mean
Element	protection level	Franken-korn	Badengold	Schwaben-spelz	Oberkulmer Rotkorn	Ostro	Ceralio	Schwaben-korn	Spelt I.N.Z.	
Zn (g kg^{-1} d.m.)	without protection	38.02	35.62	40.55	48.52	42.42	39.78	39.90	39.70	40.56
	with protection	38.22	40.52	38.33	46.64	42.28	38.23	43.25	43.74	41.40
	mean	38.12	38.07	39.44	47.58	42.35	39.01	41.58	41.72	-
LSD p = 0.05		cultivar 6.569; protection level *ns								
Cu (g kg^{-1} d.m.)	without protection	5.52	4.06	4.35	5.09	4.63	4.69	4.23	5.58	4.77
	with protection	5.17	4.22	5.35	5.45	5.07	4.85	5.03	5.55	5.09
	mean	5.35	4.14	4.85	5.27	4.85	4.77	4.63	5.57	-
LSD p = 0.05		cultivar 0.973; protection level 0.296								
Mn (g kg^{-1} d.m.)	without protection	34.12	26.52	29.74	32.43	38.18	31.28	29.22	32.25	31.72
	with protection	31.33	27.05	31.77	33.04	36.97	32.42	30.03	32.59	31.90
	mean	32.73	26.78	30.76	32.74	37.58	31.85	29.63	32.42	-
LSD p = 0.05		cultivar 4.576; protection level *ns								
Fe (g kg^{-1} d.m.)	without protection	36.43	35.03	38.40	39.13	37.57	34.37	40.37	40.33	37.70
	with protection	36.63	32.40	33.90	39.70	38.17	36.47	38.70	37.27	36.65
	mean	36.53	33.72	36.15	39.42	37.87	35.42	39.53	38.80	-
LSD p = 0.05		cultivar ns; protection level *ns								

*ns – difference not significant

compared. In turn, Kraska (2011) assessed the Fe content in spring wheat grain at a level ranging from 23.12 to 42.60 mg kg^{-1}.

Differences in the content of individual elements in spelt grain determined by various authors could have resulted from the genetic traits of the compared cultivars and different climatic, soil and agronomic conditions under which the particular cultivars were grown.

The copper content in spelt grain from the treatments where chemical crop protection was used was significantly higher than in grain from the plots where no plant protection agents were applied (Table 3). A reverse relationship was found with respect to magnesium, whose content in grain from the plots without chemical protection was significantly higher than in grain obtained from the chemically protected plot (Table 2). At the same time, the applied chemical plant protection agents did not have any significant effect on the content of N P, K, Zn, Mn, and Fe in grain. Nevertheless, under the influence of chemical crop protection, there was a tendency towards a lower content of P, K, and Fe in grain compared to the treatment without chemical protection (Tables 2, 3). On the other hand, however, a reverse trend was found with regard to the content of N, Zn, and Mn. Brzozowska and Brzozowski (2002), Kraska (2007) as well as Kraska and Pałys (2008, 2009) found no effect of herbicide application on the content of N, P, K, Mg in winter wheat and winter triticale grain. In the study of Andruszczak et al. (2009), however, the applied herbicides decreased the N content in winter wheat grain.

In each successive year of spelt monoculture cropping, the content of N, Mg, Zn, Cu, and Mn in grain decreased significantly (Table 4). This could be attributable to the deterioration of the soil chemical properties as a result of spelt monocropping. Wesołowski and Kwiatkowski (2000) as well as Woźniak (2004) draw attention to the fact that an increasing proportion of cereals in

Table 4

Chemical composition of spelt grain during the study years

Specification	Year			LSD p = 0.05
	2009	2010	2011	
N content in grain (g kg^{-1} d.m.)	26.36	22.86	21.62	0.766
P content in grain (g kg^{-1} d.m.)	4.63	4.64	4.26	0.157
K content in grain (g kg^{-1} d.m.)	2.83	3.89	3.74	0.197
Mg content in grain (g kg^{-1} d.m.)	1.69	1.59	1.41	0.089
Zn content in grain (mg kg^{-1} d.m.)	58.03	39.28	25.64	2.983
Cu content in grain (mg kg^{-1} d.m.)	6.99	4.63	3.16	0.442
Mn content in grain (mg kg^{-1} d.m.)	43.71	28.89	22.83	2.078
Fe content in grain (mg kg^{-1} d.m.)	45.18	32.83	33.53	2.696

a crop structure leads to adverse soil changes and raise the infection rate with stem base diseases over time, which in turn affects both grain yield and grain quality. The P content in grain in 2009 and 2010 was significantly higher than in 2011, whereas the K content in the first year of the study was lower than in the next two years. In turn, the Fe content was higher in 2009 than in 2010-2011 (Table 4).

CONCLUSIONS

1. The evaluated spelt wheat cultivars differed in the content of macro- and microelements in grain. Among the cultivars compared, grain of the cultivar Ostro was characterized by the highest content of N and P, while grain of cv. Franckenkorn had the highest content of K and Mg. Grain of cv. Oberkulmer Rotkorn contained the largest amount of Zn; grain of cv. Spelt I.N.Z had the highest amount of Cu, whereas grain of the cultivars Ostro and Schwabenkorn was found to have the highest amount of Mn and Fe, respectively.

2. Chemical crop protection involving the application of two herbicides, a fungicide, and a growth regulator significantly increased the copper content in spelt grain compared to the treatment in which no chemical plant protection agents were used, but it had a negative impact on the magnesium content.

3. In the last year of the study, the content of all the investigated elements in grain, except for potassium, was lower than in the first year of investigation.

REFERENCES

Andruszczak S., Kraska P., Pałys E. 2009. *The influence of different herbicide doses and foliar fertilization on quality of winter wheat grain*. Progr. Plant Prot./Post. Ochr. Rośl., 49 (1): 423-426. (in Polish)

Andruszczak S., Kraska P., Kwiecińska-Poppe E., Pałys E. 2011. *Yield of winter cultivars of spelt wheat (Triticum aestivum* ssp. *spelta* L.*) cultivated under diversified conditions of mineral fertilization and chemical protection.* Acta Sci. Pol., Agricultura, 10(4): 5-14.

Baumgärtel-Blaschke U. 1992. *Dinkel für die neue deutsche Küche*. DLG-Mitteilung en/agrar-inform, 12: 44-47.

Brzozowska I., Brzozowski J. 2002. *The influence of differentiated leaf-applied doses of Granstar 75 DF herbicide and urea on the content of crude protein and macroelements in winter wheat grain*. Pam. Puł., 130: 65-71. (in Polish)

Campbell K.G. 1997. *Spelt agronomy, genetics and breeding*. Plant Breeding Rev., 15: 188--213.

Czuba R. 2000. *The micronutrients in recent fertilization systems.* Zesz. Probl. Post. Nauk Rol., 471: 161-169. (in Polish)

GEMBARZEWSKI H. 2000. *Microelement contents and tendencies of their changing in soils and plants from arable fields in Poland.* Zesz. Probl. Post. Nauk Rol., 471: 171-179. (in Polish)

GEMBARZEWSKI H., OBOJSKI J., STRĄCZYŃSKI S., SIENKIEWICZ U. 1995. *The content of macro- and micronutrients in soils as well as in potato and wheat plants grown in high productivity fields*. IUNG Puławy, S(80): 1-38. (in Polish)

GRELA E.R. 1996. *Nutrient composition and content of antinutritional factors in spelt (Triticum spelta* L*) cultivars*. J. Sci. Food Agric., 71: 399-404.

KOCOŃ A. 2005. *Fertilization of quality spring and winter wheat and its impact on yield and grain quality.* Pam. Puł., 139: 55-64. (in Polish)

KORZENIOWSKA J. 2008. *Importance of copper deficiency in wheat cultivation.* Post. Nauk Rol., 4-5: 15-31. (in Polish)

KORZENIOWSKA J., STANISŁAWSKA-GLUBIAK E. 2011. *The effect of foliar application of copper on content of this element in winter wheat grain.* Pol. J. Agron., 4: 3-6.

KRASKA P. 2007. *The influence of different doses of herbicides on yielding and macroelements content in winter grain.* Biul. IHAR, 246: 23-30. (in Polish)

KRASKA P. 2011. *The content of some elements in the grain of spring wheat cv. Zebra depending on soil tillage systems and catch crops*. J. Elem., 16(3): 407-419. DOI:10.5601/ /jelem.2011.16.3.06

KRASKA P., PAŁYS E. 2008. *Grain yielding and chemical composition of winter triticale cultivated in monoculture in conditions of different doses herbicides*. Ann. UMCS, Sect. E, 63(2): 1-7. DOI:10.2478/v10081-008-0015-4. (in Polish)

KRASKA P., PAŁYS E. 2009. *Yielding and chemical composition of winter wheat grain cultivated in monoculture in conditions of differentiated doses of herbicides application*. Progr. Plant Prot./Post. Ochr. Rośl., 49 (1): 440-444. (in Polish)

KWIECIŃSKA-POPPE E., ANDRUSZCZAK S., KRASKA P., PAŁYS E. 2011. *The influence of chemical protection levels on quality of spelt wheat (Triticum spelta* L.*) grain*. Progr. Plant Prot./ Post. Ochr. Rośl., 51 (2): 986-989. (in Polish).

MULARCZYK A., NARKIEWICZ-JODKO M., GIL Z., URBAN M. 2010. *The influence of herbicides on health and quality of winter wheat grain depending on weather conditions*. Progr. Plant Prot./Post. Ochr. Rośl., 50 (1): 482-490. (in Polish)

NARKIEWICZ-JODKO M., GIL Z., URBAN M. 2002. *Health and quality features of four cultivars of winter wheat in relation to herbicide applications.* Progr. Plant Prot./Post. Ochr. Rośl., 42 (2): 530-534. (in Polish)

PAŁYS E., ŁABUDA S. 1997. *Yielding and elemental composition of spelt wheat grain and strow*. Rachis, 16 (1/2): 67-70.

PAŁYS E., KURASZKIEWICZ R. 2003. *The influence of sowing time on selected characters and corn yield of spelt (Triticum aestivum* ssp. *spelta)*. Biul. IHAR, 228: 71-80. (in Polish)

RACHOŃ L., SZUMIŁO G. 2009. *Comparison of chemical composition of selected winter wheat species*. J. Elementol., 14(1): 135-146.

STANISŁAWSKA-GLUBIAK E., KORZENIOWSKA J. 2007. *Principles of micronutrient fertilization of crop plants.* Stud. Rozpr. IUNG – PIB, 8: 99-110. (in Polish)

STANISŁAWSKA-GLUBIAK E., KORZENIOWSKA J. 2011. *Impact of zero tillage system on the nutrient content of grain and vegetative parts of cereals*. Pol. J. Agron., 4: 29-32.

STANISŁAWSKA-GLUBIAK E., STRĄCZYŃSKI S., SIENKIEWICZ-CHOLEWA U. 1996. *Effect of yield level differentiation on micronutrient content in wheat grain.* Zesz. Probl. Post. Nauk Rol., 434: 77-81. (in Polish)

SULEWSKA H. 2004a. *Influence of some agrotechnical treatments on yielding and grain chemical composition of winter form of spelt (Triticum aestivum* ssp. *spelta).* Pam. Puł., 135: 285-293. (in Polish)

SULEWSKA H. 2004b. *Characterization of 22 spelt (Triticum aestivum* ssp. *spelta) genotypes relating to some features*. Biul. IHAR, 231: 43-53. (in Polish)

SULEWSKA H. KOZIARA W., PANASIEWICZ K., PTASZYŃSKA G., MOROZOWSKA M. 2008. *Chemical composition of grain and protein yield of spelt varieties depended on selected agrotechnical factors*. J. Res. Appl. Agric. Engin., 53(4): 92-95. (in Polish)

TYBURSKI J., ŻUK-GOŁASZEWSKA K. 2005. *Wheat spelt – the cereal of our ancestors*. Post. Nauk Rol., 4:3-13. (in Polish)

WESOŁOWSKI M., KWIATKOWSKI C., 2000. *Yielding and weed infestation of inter-variety mixtures of spring barley in many year monoculture.* Rocz. AR Pozn. 325, Rol., 58: 135-144. (in Polish)

WINZELER H., RÜEGGER A. 1990. *Winkel: Renaissance einer alten Getreideart.* Landwirtschaft Schweiz., 3(9): 503-511.

WOŹNIAK A. 2004. *The yield and quality of grain of spring wheat in different crop rotations*. Zesz. Nauk. AR Wrocław 487, Rol., 85: 219-227. (in Polish)