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Application of reduced doses of chlorsulfuron in semi-dwarf and full-height cultivars of winter triticale

Sylwia Kaczmarek, Kinga Matysiak*

Weed Science and Plant Protection Techniques Department, Institute of Plant Protection – National Research Institute, Władysława Węgorka 20, 60-318 Poznań, Poland

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Abstract: The aim of the field experiments carried out in the years 2009–2011 was to assess the application of reduced doses of chlorsulfuron on yield and quality parameters of winter triticale semi-dwarf and full-height cultivars. The herbicide effect was evaluated in two cultivars, Grenado and Pizarro. The cultivars were of different plant heights. Chlorsulfuron was applied at the recommended dose (15 g a.i. · ha^{-1}), at areduced dose (10.5 g a.i. · ha^{-1}) and at areduced dose with an adjuvant. Treatments with the herbicide were conducted directly after the triticale had been sown. Visual assessment of weed infestation was carried out in spring, after the start of the vegetation of the cultivated plant. The study assessed triticale grain yield, grain number per ear, thousand grain weight, and selected qualitative parameters of grain (protein and starch content). The obtained data proved the usefulness of reduced doses of chlorsulfuron in weed control both separately and in a combination with the adjuvant. The average percent of the weed control was very high for both cultivars and for the assessed doses of herbicide. Both experimental factors (herbicide dose and triticale cultivar) influenced the level of the obtained grain yield of triticale, and the thousand kernel weight. While grain number per ear and protein and starch content depended only on the examined cultivar.

Key words: adjuvant, chlorsulfuron, cultivars, reduced dose, winter triticale

Introduction

The area of triticale cultivation in Poland as well as the area of this cereal's crops have exhibited great changes. Currently the share of triticale in the cropping system is significant. In 2011, triticale cultivation covered an area of ca. 1.3 mln ha. The nutritional value of triticale grain is due to: the high protein content, a favorable amino acid composition, and a high coefficient of digestibility. In Poland, the area of triticale cultivation has grown slowly but steadily. In 2009, the area of sown triticale exceeded the area of cultivated rye.

Currently triticale is a well-established crop, having equal status with other species of cereals (Maćkowiak 2003).

The percent of farms involved in triticale cultivation in Poland, according to the total number of farms involved in cereal cultivation, was 31.7% for the winter triticale type and 5.2% for the spring type (GUS 2014).

Triticale has highly adapted to all the regions in Poland (Arseniuk and Oleksiak 2004) but most triticale (21–26%) is grown in the central, northern, and north-western region of Poland (GUS 2012).

Cultivars of cultivated plants have a wide range of competitive abilities which can be a useful tool in integrated weed management (IWM) (Christensen 1994). It should be emphasised that cultivar potential may be combined with other tools used in IWM, e.g. reduced herbicide doses.

At present, the main goal of weed management is to keep weed infestation at an acceptable level. The application of herbicides at reduced doses are often sufficient.

Moreover, the addition of an adjuvant improves treatment efficacy and can compensate for a reduced dose of herbicide (Kwiatkowski *et al.* 2011; Javaid *et al.* 2012).

The role of integrated weed management has also been noted by other authors (Fathi 2005; Ullah *et al.* 2008; Marwat *et al*. 2011). The various competitive abilities cultivars have against weeds were pointed out by Kraska (2008) and Watson *et al.* (2006), among others.

Experiments aimed at the possibility of reducing the use of herbicides have repeatedly confirmed the usefulness of such solutions in agricultural production (Kraska 2008; Barros *et al.* 2011). Scientific research has also devoted much attention to the response of cultivars of cultivated plants to herbicides (Bailey *et al*. 2004; Hassan *et al*. 2010; Weber and Kieloch 2013).

Triticale is considered a cereal with high yielding potential. It is stated to be more competitive against weeds than wheat (Oettler 2005). It is more tolerant against drought and pests (Darvey *et al*. 2000; Erekul and Köhn 2006). The importance of the genetic variability of cultivated plants has been addressed by many authors (Mittal and Sethi 2005; Barnett *et al*. 2006; Theimt and Oettler 2008).

*Corresponding address:
s.kaczmarek@iorpib.poznan.pl

The aim of our study was to assess the possibility of reducing the doses of chlorsulfuron in the cultivation of winter triticale. Two triticale cultivars were taken into consideration, and the application of a reduced dose of herbicide with an adjuvant were also taken into consideration, for the assessment of the chlorsulfuron reduction in the cultivation of winter triticale.

Materials and Methods

The experiments

Field experiments were carried out in the years 2009/2010 and 2010/2011 in the Field Experimental Station of the Institute of Plant Protection – State Research Institute, located ca. 60 km from Poznań (52°12′36′′N, 17°26′4′′E).

In the vegetation season 2009/2010, the experiment was located on podsolic soil derived from light loamy sand, of soil quality class Iva. The soil pH was 5.0 and the organic matter content was 1.14%. In autumn, prior to sowing, the following mineral fertilisation was applied: N = 20 kg · ha^{-1}, P = 60 kg · ha^{-1} and K = 60 kg · ha^{-1}, while in spring N = 80 kg · ha^{-1}. In the season 2010/2011, the experiment was established on podsolic soil derived from loamy sand of soil quality class IIIa. The soil pH was 5.1 and the organic matter content 1.35%. Prior to plant sowing, the following nutrients were used: N = 20 kg · ha^{-1}, P = 60 kg · ha^{-1} and K = 60 kg · ha^{-1}, and in spring N = = 71 kg · ha^{-1}, P = 71 kg · ha^{-1} and K = 71 kg · ha^{-1}. In 2009, a forecrop for winter triticale was winter rape, and in 2010 – winter wheat. The experimental plots had a surface area of 16.5 m^2 (width of 1.5 m, length of 11.5 m). The inter-row spacing was 12.5 cm.

The two factors examined in the field experiments were herbicide dose (factor A) and winter triticale variety (factor B). The experiment was carried out in a randomised block design with four replications.

The experiments used chlorsulfuron – 2-chloro-N-[[(4--methoxy-6-methyl-1,3,5-triazin-2-yl)amino]carbonyl]benzenesulfonamide (a compound of the group of sulfonylurea derivatives) – Maczuga 75 WG, in the form of pellets for aqueous suspension. The following doses of active ingredient per 1 ha were used: 15 g · ha^{-1}, 10.5 g · ha^{-1} and 10.5 g · ha^{-1} with an oil adjuvant (Atpolan 80 EC at a dose of 1.5 l · ha^{-1} – 76% paraffin oil). The herbicide effect was compared to the control which was without herbicide use (0 g a.i. · ha^{-1}). The treatments were carried out directly after the sowing of the winter triticale. A pressure field sprayer was used. The sprayer had a tank volume of 4 l, a working pressure of 2 bars, a nozzle spacing of 50 cm, and an application rate of 200 l · ha^{-1}. The sprayer beam mounting was 50 cm and the working speed was 5 km per hour.

Two winter triticale cultivars were used in the study: Grenado and Pizarro, registered in Poland, respectively, in 2007 and 2008. The two cultivars differ in plant height. Cultivar Pizarro is a full-height cultivar, while the stalk of Grenado is shorter by about 20% in comparison with the Pizarro cultivar. The sowing date was the first decade of October for both years. The seeding rate of winter triticale (with kernel density per surface area of 1 m^2 amounting to 400 kernels/m^2 for cultivar Grenado and 380 kernels/m^2 for cultivar Pizarro) was, respectively, for the years: the Grenado cultivar – 161 kg · ha^{-1} (2010) and 157 kg · ha^{-1} (2011), while for Pizarro – 192 kg · ha^{-1} (2010) and 212 kg · ha^{-1} (2011).

Weed infestation

Analysis of weed infestation of triticale was carried out in spring, after the start of vegetation. Species composition and number of individual weed species (calculated per 1 m^2) were determined on the plots without herbicide use. The percentage of weed control in the objects of the treatment was assessed using the estimation method. The number and condition of the plants were taken into account when comparing the plants with the control. The European and Mediterranean Plant Protection Organisation (EPPO) standards were followed.

Analysis and parameters of the yield

From each plot, twenty-five triticale ears of the cultivated plant were collected before harvesting. Grain number per ear was determined on the basis of the threshed sample. Triticale grain was collected with a Wintersteiger Classic plot combine. Grain yield was determined at 14% grain moisture and then calculated per surface area of 1 ha. The thousand kernel weight was assessed on the basis of the grain sample. The qualitative grain analysis (starch and protein content) was conducted with an InfratecTM 1241 Grain Analyser (FOSS).

Statistical analysis

The results of the research were subjected to statistical analysis for two-factor experiments, in accordance with the experiment model, with the use of FR – ANALWAR – 4.3 software. The significance of differences was assessed with Tukey's confidence half-interval at a significance level of p = 0.05.

Results and Discussion

Weed infestation

During the years that the research took place, 10 weed species were noted, however, assessment of herbicide effectiveness was made for seven species of which there was a prevalence of at least 4 plants · m^{-2}. Predominant species in weed assemblage included: *Centaurea cyanus* L., *Matricaria inodora* L. and *Viola arvensis* Murr. On the basis of the weed infestation analysis, it can be concluded that chlorsulfuron was effective for controlling weeds (Table 1). The mean effectiveness of weed control was very satisfactory in both cultivars and exceeded 90%. Almost all weed species were very well-controlled by chlorsulfuron. The weeds were also very well-controlled with the use of the reduced dose, and the reduced dose with an adjuvant of herbicide. Only *C. cyanus* was less sensitive to chlorsulfuron, and its lowest control was observed after application of a reduced dose without an adjuvat (10.5 g · ha^{-1}) in the cultivar Grenado.

Table 1. Efficacy of herbicides applied in triticale cultivation (visual assessment)

Treatment	Triticale variety	% of weed control							
		BRSNN	CAPBP	CENCY	GERPU	MATIN	THLAR	VIOAR	Total/ Average
The control [no.· m^{-2}]	Grenado	4,0	4,0	7,0	4,0	5,0	4,0	5,0	33
	Pizarro	4,0	4,0	6,0	4,0	6,0	4,0	6,0	34
Chlorsulfuron 15.0 g · ha^{-1}	Grenado	100	100	84	100	98	100	95	97
	Pizarro	100	100	90	98	98	100	97	98
Chlorsulfuron 10.5 g · ha^{-1}	Grenado	100	100	70	93	100	100	94	94
	Pizarro	100	100	85	95	99	100	94	96
Chlorsulfuron 10.5 g · ha^{-1} + adjuvant	Grenado	100	100	81	100	98	100	93	96
	Pizarro	100	100	88	95	98	100	94	96

BRSNN – *Brassica napus* L., CAPBP – *Capsella bursa-pastoris* (L.) Medik., CENCY – *Centaurea cyanus* L., GERPU – *Geranium pusillum* L., MATIN – *Matricaria inodora* L., THLAR – *Thlaspi arvense* L., VIOAR – *Viola arvensis* Murr.

In many cases, the studies on cereals confirm differences in the competitiveness of cultivars against weeds (Cousens and Mokhtari 1998; Lemerle *et al*. 2001; Didon 2002). O'Donovan *et al*. (2000) demonstrated that semi-dwarf cultivars were less competitive when compared to cultivars with full-length stalks. Lanning *et al*. (1997) did not confirm the correlation between plant height and competitiveness of oat. However, our previous research (Kaczmarek *et al*. 2009) on winter wheat revealed that cultivars competing more strongly with weeds were cultivars with higher/taller plants. Kraska (2008) stated that triticale cultivars did not affect the level of weed infestation with: *V. arvensis*, *M. maritima*, *Chenopodium album* L., and *Apera spica-venti* (L.) P. Beauv. Yamauti *et al*. (2011) demonstrated the competitive effect of triticale using the example of *Raphanus raphanistrum* L.

As in our research, the effectiveness of reduced doses of herbicides of the sulfonylurea herbicide group has been confirmed by other authors (Nadeem *et al*. 2008; Barros *et al*. 2009; Barros *et al*. 2011; Kieloch and Domaradzki 2011; Buczek *et al*. 2012).

Yield and yield parameters

The level of collected grain yield differed depending on the chlorsulfuron dose as well as the examined triticale cultivar. Interactions between the examined experimental factors were found in 2011 (Table 2).

Weather conditions affected the yielding of winter triticale. Differences in grain yield were especially noticeable in 2010, when a high amount of precipitation was noted in May and August. In 2010, the cultivar Grenado had a yield which was lower by 67% than that of the cultivar Pizarro, while in the following year Grenado was the cultivar with a higher yield (an increase in yield by 10% in comparison with Pizarro). The influence of weather conditions on the yielding of cultivar Grenado, was also observed by Brzozowska and Brzozowski (2011). On average, for the years of the research, the highest significant grain yields were noted in the objects where the recommended herbicide dose was applied. However, in all the objects where chlorsulfuron was used, grain yields differed significantly from those yields collected in the control. Additionally, no significant differences between a reduced dose, and a reduced dose applied with an adjuvant, were found.

Grain number per ear depended on the examined triticale cultivar. The Grenado cultivar had a greater grain number when compared to the Pizarro cultivar (Table 3). However, both herbicide dose and cultivar affected thousand kernel weight (Table 4). Unlike the grain number per ear, a higher thousand kernel weight was noted for the Pizarro cultivar. A significant increase in kernel weight, when compared to the control, was observed only in the objects where the reduced dose of chlorsulfuron was used (but did not affect yields). What is more, kernel weight did not differ between the doses: recommended, reduced, and reduced with an adjuvant.

Analysis of qualitative traits of triticale grain showed that the content of protein and gluten depended on the triticale cultivar (Tables 5, 6). Higher grain protein content was noted for the cultivar Pizarro. The opposite results were obtained for grain starch content, which was higher for the cultivar Grenado.

Marczewska (2006) found chlorsulfuron as a selective active ingredient in winter wheat used to analyse the yield and its quantitative parameters.

Research conducted by Rola and Kieloch (2006) indicated that chlorosulfuron applied in a few winter wheat cultivars did not significantly affect differences in the yield and its structure.

Different conclusions were drawn by other authors. Rengel and Wheal (1997) noted an influence of chlorsulfuron on root growth and uptake of nutrients. O'Keeffe and Wilhelm (1993) and Pederson *et al*. (1994) also observed the influence of sulfonylurea herbicides on the reduction in growth and yield of cultivated plants. Different responses of triticale cultivars to herbicides were noted in a study by Murkowski and Skórska (1994) who used luminescence tests. Ratz *et al*. (2011) confirmed the

Table 2. Winter triticale grain yield (t · ha^{-1})

Treatment	2010		2011		Average from the years	
	Grenado	Pizarro	Grenado	Pizarro	Grenado	Pizarro
The control	2.4	7.8	6.8	6.1	4.6	6.9
Chlorosulfuron 15.0 g	2.9	8.6	7.7	6.9	5.3	7.7
Chlorosulfuron 10.5 g	2.9	8.2	7.0	6.6	4.9	7.4
Chlorosulfuron 10.5 g + adjuvant	2.8	8.3	7.3	6.4	5.0	7.3
Average for the dose:						
0 l/ha	5.07		6.43		5.75	
15.0 g	5.73		7.28		6.50	
10.5 g	5.54		6.78		6.16	
10.5 g + adjuvant	5.53		6.82		6.17	
Average for the cultivar:						
Grenado	2.73		7.17		4.95	
Pizarro	8.20		6.49		7.34	
LSD (0.05)						
Factor A – dose	0.26		0.22		0.14	
Factor B – cultivar	0.14		0.12		0.07	
A(B)	ns		0.31		ns	
B(A)	ns		0.23		ns	

ns – no significant difference

Table 3. Grain number per ear of winter triticale (no.)

Treatment	2010		2011		Average from the years	
	Grenado	Pizarro	Grenado	Pizarro	Grenado	Pizarro
The control	50	51	56	50	53	51
Chlorosulfuron 15.0 g	48	52	58	50	53	51
Chlorosulfuron 10.5 g	49	55	61	50	55	52
Chlorosulfuron 10.5 g + adjuvant	51	52	57	48	54	50
Average for the dose:						
0 l/ha	51		53		52	
15.0 g	50		54		52	
10.5 g	52		55		54	
10.5 g + adjuvant	52		53		52	
Average for the cultivar:						
Grenado	50		58		54	
Pizarro	53		49		51	
LSD (0.05)						
Factor A – dose	ns		ns		ns	
Factor B – cultivar	3.0		4.1		2.6	
A(B)	ns		ns		ns	
B(A)	ns		ns		ns	

ns – no significant difference

Table 4. 1,000 grain weight of winter triticale (g)

Treatment	2010		2011		Average from the years	
	Grenado	Pizarro	Grenado	Pizarro	Grenado	Pizarro
The control	31.6	31.8	37.5	41.0	34.5	36.4
Chlorosulfuron 15.0 g	32.0	32.0	38.9	41.7	35.4	36.9
Chlorosulfuron 10.5 g	32.6	32.8	39.9	41.3	36.2	37.1
Chlorosulfuron 10.5 g + adjuvant	31.9	32.6	38.8	41.2	35.4	36.9
Average for the dose:						
0 l/ha	31.7		39.2		35.4	
15.0 g	32.0		40.3		36.2	
10.5 g	32.7		40.6		36.6	
10.5 g + adjuvant	32.3		40.0		36.1	
Average for the cultivar:						
Grenado	32.0		38.8		35.4	
Pizarro	32.3		41.3		36.8	
LSD (0.05)						
Factor A – dose	0.95		0.97		0.89	
Factor B – cultivar	ns		0.51		0.47	
A(B)	ns		1.36		ns	
B(A)	ns		1.02		ns	

ns – no significant difference

Table 5. Protein content in winter triticale grain (%)

Treatment	2010		2011		Average from the years	
	Grenado	Pizarro	Grenado	Pizarro	Grenado	Pizarro
The control	11.0	10.9	8.0	10.5	9.9	10.7
Chlorosulfuron 15.0 g	10.7	10.4	9.2	10.5	10.0	10.5
Chlorosulfuron 10.5 g	10.6	10.6	9.4	10.4	10.0	10.5
Chlorosulfuron 10.5 g + adjuvant	10.9	10.3	8.8	10.8	9.8	10.5
Average for the dose:						
0 l/ha	11.0		9.7		10.3	
15.0 g	10.6		9.9		10.2	
10.5 g	10.6		9.9		10.2	
10.5 g + adjuvant	10.6		9.8		10.2	
Average for the cultivar:						
Grenado	10.8		9.0		9.9	
Pizarro	10.6		10.5		10.5	
LSD (0.05)						
Factor A – dose	ns		ns		ns	
Factor B – cultivar	ns		0.59		0.40	
A(B)	ns		ns		ns	
B(A)	ns		ns		ns	

ns – no significant difference

Table 6. Starch content in winter triticale grain (%)

Treatment	2010		2011		Average from the years	
	Grenado	Pizarro	Grenado	Pizarro	Grenado	Pizarro
The control	59.7	59.6	61.7	59.5	60.7	59.6
Chlorosulfuron 15.0 g	60.0	59.7	61.9	59.5	60.9	59.6
Chlorosulfuron 10.5 g	59.9	59.8	61.6	59.1	60.7	59.4
Chlorosulfuron 10.5 g + adjuvant	60.0	60.1	61.6	59.1	60.8	59.6
Average for the dose:						
0 l/ha	59.6		60.6		60.1	
15.0 g	59.9		60.7		60.3	
10.5 g	59.8		60.3		60.1	
10.5 g + adjuvant	60.0		60.4		60.2	
Average for the cultivar:						
Grenado	59.9		61.7		60.8	
Pizarro	59.8		59.3		59.5	
LSD (0.05)						
Factor A – dose	ns		ns		ns	
Factor B – cultivar	ns		0.42		0.29	
A(B)	ns		ns		ns	
B(A)	ns		ns		ns	

ns – no significant difference

selectiveness of substances florasulam + MCPA and thifensulfuron-methyl towards triticale.

Kwiecińska-Poppe *et al*. (2010) demonstrated that crude protein and starch content in the grain of winter triticale was statistically higher in the objects where reduced doses of herbicides were used, in comparison with the objects with full herbicide dose, and the control. However, Stankiewicz (2004) did not observe a significant influence of applied herbicide doses on the quality of triticale grain.

Other aspects of herbicide use in triticale cultivation have also been addressed in literature. For instance, Kurowski *et al*. (2004) noted that tribenuron-methyl and a mixture of 2,4-D + dicamba favorably affect the health of triticale, while substances MCPA and florasulam + 2,4-D undermine it. The research by Kurowski *et al*. (2010) also confirmed the influence of weed infestation regulation on an increase in prevalence of diseases of triticale leaves.

It can be concluded, that chlorsulfuron applied at a reduced dose, and at a reduced dose with an adjuvant gave a sufficient weed control effect, without a decrease in grain yield and without a significant effect on the yield parameters.

References

Arseniuk E., Oleksiak T. 2004. Triticale in Poland. p. 131–135. In: "Triticale Improvement and Production" (M. Mergoum, H. Gomez-Macpherson, eds.). Food and Agricultural Organization of the United Nation, Rome, 2004, 154 pp.

Bailey W.A., Wilson H.P., Brann D.E., Griffey C.A. 2004. Wheat cultivar tolerance to AE F130060 03. Weed Technology 18 (4): 881–886.

Barnett R.D., Blount A.R., Pfahler P.L., Bruckner P.L., Wesenberg D.M., Johnson J.W. 2006. Environmental stability and heritability estimates for grain yield and test weight in triticale. Journal of Applied Genetics 47 (3): 207–213.

Barros J.F.C., Basch G., Freixial R., Carvalho M. 2009. Effect of reduced doses of mesosulfuron + iodosulfuron to control weeds in no-till wheat under Mediterranean conditions. Spanish Journal of Agricultural Research 7 (4): 905–912.

Barros J.C., Basch G., Calado J.G., Carvalho M. 2011. Reduced doses of herbicides to control weeds in barley crops under temperate climate conditions. Revista Brasileira Ciências Agrárias Recife 6 (2): 197–202.

Brzozowska I., Brzozowski J. 2011. Effectivenes of weed control and the yield of winter triticale depending on the tending method and nitrogen fertilization. Acta Scientiarum Polonorum, Agricultura 10 (4): 25–33.

Buczek J., Szpunar-Krok E., Tobiasz-Salach R., Bobrecka-Jamro D. 2012. Influence of sowing density and dose tribenuronmetyl on weed infestation in spring wheat. Progress of Plant Protection/Postępy w Ochronie Roślin 52 (1): 62–66. (in Polish with English summary)

Christensen S. 1994. Crop weed competition and herbicide performance in cereal species and varieties. Weed Research 34 (1): 29–36.

Cousens R.D., Mokhtari S. 1998. Sesonal and site variability in the tolerance of wheat cultivars to interference from *Lolium rigidum*. Weed Research 38 (4): 301–307.

Darvey N.L., Gustafson J.P., Naeem H. 2000. Triticale: Production and Utilization. p. 257–274. In: "Handbook of Cereal Science and Technology" (K. Kulp, J.G. Ponte, eds.), Marcel Dekker, Inc. New York, 808 pp.

Didon U.M.E. 2002. Variation between cultivars in early response to weed competition. Journal of Agronomy and Crop Science 188 (3): 176–184.

Erekul O., Köhn W. 2006. Effect of weather and soil conditions on yield components and bread-making quality of winter wheat (*Triticum aestivum* L.) and winter triticale (*Triticosecale* Wittm.) varieties in north-east Germany. Journal of Agronomy and Crop Science 192 (6): 452–464.

Fathi G. 2005. Integrated weed management in canola. Turkish Journal of Field Crops 10 (2): 57–63.

Główny Urząd Statystyczny 2014. Charakterystyka gospodarstw rolnych w 2013 r. [Characteristic of farms in 2013]. http://stat.gov.pl/obszary-tematyczne/rolnictwo-lesnictwo/rolnictwo/charakterystyka-gospodarstw-rolnych-w-2013-r-,5,4.html. [Accessed: June 20, 2014]. (in Polish)

Główny Urząd Statystyczny 2012. Powszechny Spis Rolny 2010 – Uprawy rolne i wybrane elementy metod produkcji roślinnej. [Agricultural Census 2010 – Crop and selected elements of crop production methods]. http://stat.gov.pl/obszary-tematyczne/rolnictwo-lesnictwo/psr-2010/powszechny-spis-rolny-2010-uprawy-rolne-i-wybrane-elementy-metod-produkcji-roslinnej,4,1.html. [Accessed: June 20, 2014]. (in Polish)

Hassan G., Tanveer S., Khan N.U., Munir M. 2010. Integrating cultivars with reduced herbicide rates for weed management in maize. Pakistan Journal of Botany 42 (3): 1923–1929.

Javaid M.M., Tanveer A., Ahmad R., Yaseen M., Khaliq A. 2012. Optimizing activity of herbicides at reduced rate on Emex spinosa campd. with adjuvants. Planta Daninha 30 (2): 425–435.

Kaczmarek S., Kierzek R., Gruchot D. 2009. Winter wheat response to application of reduced doses of fluroxypyr + 2,4 D. Bulletin of Institute of Plant Breeding and Acclimatization 254: 13–20.

Kieloch R., Domaradzki K. 2011. The role of the growth stage of weeds in their response to reduced herbicide doses. Acta Agrobotanica 64 (4): 259–266.

Kraska P. 2008. The influence of different herbicide doses on weed infestation of winter triticale cultivated in monoculture. Acta Agrobotanica 61 (2): 229–238.

Kurowski T.P., Brzozowska I., Brzozowski J. 2004. The effect of application of different herbicides and herbicides combined with urea on the sanitary state of winter triticale. Annales Universitatis Mariae Curie-Skłodowska, Sectio E, 59 (3): 1267–1274.

Kurowski T.P., Brzozowska I., Brzozowski J., Kurowska A. 2010. Health status of winter triticale as dependent on weed control, nitrogen fertilization and protection against pathogens. Annales Universitatis Mariae Curie-Skłodowska, Sectio E, 65 (2): 10–21.

Kwiatkowski C., Wesołowski M., Juszczak J. 2011. Effect of adjuvants and reduced doses of pesticides on nutrient composition of spring barley grain. Acta Agrophysica 17 (2): 345–357.

Kwiecińska-Poppe E., Kraska P., Andruszczak S., Pałys E. 2010. Yield and some grain quality characteristics of winter triticosecale cultivated in monoculture in conditions of application of different herbicide doses and foliar fertilization. Progress of Plant Protection/Postępy w Ochronie Roślin 50 (2): 999–1003. (in Polish with English summary)

Lanning S.P., Talbert L.E., Martin J.N., Blake T.K., Bruckner P.L. 1997. Genotype of wheat and barley affects light penetration and wild oat growth. Agronomy Journal 89 (1): 100–103.

Lemerle D., Verbeck B., Orchard B. 2001. Ranking the ability of wheat varieties to compete with *Lolium rigidum*. Weed Research 41 (3): 197–209.

Maćkowiak W. 2003. Estimation of progress and strategic directions of triticale breeding in Poland. Institute of Plant Breeding and Acclimatization 230: 127–141.

Marczewska K. 2006. Phytotoxicity and efficacy of chlorsulfuron in winter wheat. Journal of Plant Protection Research 46 (4): 387–396.

Marwat K.B., Azim Khan M., Hashim S., Nawab K., Khattak A.M. 2011. Integrated weed management in wheat. Pakistan Journal of Botany 43 (1): 625–633.

Mittal R.K., Sethi G.S. 2005. Genetic variability in triticale x bread wheat derivatives under normal and phosphorus stress regimes. Journal of Environmental Biology 26 (1): 105–107.

Murkowski A., Skórska E. 1994. Estimation of Triticale varieties susceptibility on some herbicides by means of luminescence tests. Zeszyty Naukowe – Akademia Rolnicza w Szczecinie 162: 179–183. (in Polish)

Nadeem M.A., Ahmad R., Khalid M., Naveed M., Tanveer A., Ahmad J.N. 2008. Growth and yield response of autumn planted maize (*Zea mays* L.) and its weeds to reduced doses of herbicide application in combination with urea. Pakistan Journal of Botany 40 (2): 667–676.

O'Donovan J.T., Harker K.N., Clayton G.W., Hall L.M. 2000. Wild oat (*Avena fatua*) interference in barley (*Hordeum vulgare*) is influenced by barley variety and seeding rate. Weed Technology 14 (3): 624–629.

Oettler G. 2005. The fortune of a botanical curiosity – Triticale: past, present and future. The Journal of Agriculture Science 143 (5): 329–346.

O'Keffe P., Wilhelm N. 1993. The hidden costs of herbicide use on micronutrient-poor soils. In: "Farming – from Paddockk to Plate" (G.K. McDonald, W.D. Bellotti, eds.). Proceedings of the 7th Australian Agronomy Conference. The University of Adelaide, Adelaide, south Australia, 19–24 September 1993. www.regional.org.au/au/asa/1993/concurrent/weeds/p-02.htm [Accessed: May 20, 2014].

Pederson R.N., Black I.D., Dyson C.B., Hannam R.J. 1994. Effects of the herbicide metsulfuron-methyl on root length, nutrient levels, grain protein, and yield of barley. Australian Journal of Experimental Agriculture 34 (4): 499–504.

Raatz L., Hills M., McKenzie R., Yang R.C., Topinka K., Hall L. 2011. Tolerance of spring triticale (×*Triticosecale* Wittmack) to four wheat herbicides. Weed Technology 25 (1): 84–89.

Rengel Z., Wheal M.S. 1997. Herbicide chlorsulfuron decreases growth of fine roots and micronutrient uptake in wheat genotypes. Journal of Experimental Botany 48 (309): 927–934.

Rola H., Kieloch R. 2006. Reaction of winter wheat cultivars to chlorsulfuron applied in the autumn and in the spring. Progress of Plant Protection/Postępy w Ochronie Roślin 46 (2): 261–264. (in Polish with English summary)

Stankiewicz C. 2004. Effect of sowing density, herbicides and harrowing application on yield and content of total protein and starch in 'Wanad' spring triticale kernels. Acta Scientiarum Polonorum, Agricultura 3 (2): 77–88.

Theimt E.M., Oettler G. 2008. Agronomic performance of anther-derived doubled haploid and single seed descent lines in crosses between primary and secondary winter triticale. Plant Breeding 127 (5): 476–479.

Ullah W., Azim Khan M., Arifullah A., Sadiq M. 2008. Evaluation of integrated management practices for maize. Pakistan Journal of Weed Science Research 14 (1–2): 19–32.

Watson P.R., Derksen D.A., Acker R. 2006. The ability of 29 barley cultivars to compete and withstand competition. Weed Science 54 (4): 783–792.

Weber R., Kieloch R. 2013. Influence of herbicides on yield stability of winter wheat cultivars under different sowing rates. International Journal of Plant Production 7 (1): 55–65.

Yamauti M.S., Costa Aguiar Alves P.L., Carvalho L.B. 2011. Competitive interactions of triticale (*Triticum turgidsecale*) and jointed charlock (*Raphanus raphanistrum*) in function of plant population and proportion. Planta Daninha 29 (1): 129–135.