NARDI FUNDULEA, ROMANIA
www.incda-fundulea.ro

ROMANIAN AGRICULTURAL RESEARCH, NO. 34, 2017
Print ISSN 1222-4227; Online ISSN 2067-5720

WHEAT CULTIVARS, THEIR MIXTURES AND REDUCED HERBICIDE DOSES AS A PRACTICAL SOLUTION IN INTEGRATED WEED MANAGEMENT

Sylwia Kaczmarek* **and Kinga Matysiak**

Department of Weed Science and Plant Protection Techniques
Institute of Plant Protection – National Research Institute, 20 Władysława Węgorka Street, 60-318 Poznań, Poland.
*Corresponding author. E-mail: ior.poznan.sylwia@gmail.com

ABSTRACT

The aim of field experiments carried out in the years 2011-2012 was to assess the possibility of exploitation of potential of spring wheat cultivars, their mixtures and reduced doses of substances: iodosulfuron-methyl-sodium + propoxycarbazone-sodium + amidosulfuron, as elements of integrated plant protection against weeds. The research was conducted on spring wheat cultivars Bombona and Waluta, sown individually and in mixtures (50%+50%). The herbicide was applied at the doses of 300 g·ha^{-1}, 150 g·ha^{-1} and 150 g·ha^{-1} with adjuvant. Analysis of weed infestation (weeds number and fresh weight) was carried out, and yield and its quantitative and qualitative parameters (grain number per ear, thousand grain weight, content of protein, starch and gluten, Zeleny sedimentation index, grain bulk density) were assessed. The results showed that both the herbicide doses and the cultivars affected the level of weed infestation. Cultivar Bombona was characterized by significantly lower weed infestation than cultivar Waluta. Additionally, sowing of the cultivars in the mixture increased the level of competitiveness against weeds. The possibility of herbicide application at the reduced doses was confirmed for the both cultivars, which significantly increased grain yield when compared to that from control. The analyzed experimental factors affected quantitative and qualitative parameters of wheat grain.

Key words: amidosulfuron, competition, cultivar mixtures, iodosulfuron-methyl-sodium, propoxycarbazone-sodium.

INTRODUCTION

An important stage of plant protection development was appearance of the precision control concept. Introduction of the method of control was conditioned by development of methods of inspection of crops and economic thresholds (Stern, 1973). The concept of integrated control was formulated together with the concept of precision control (Stern et al., 1959), which has been confirmed by numerous studies of many scientists who took up the subject of alternative solutions or solutions complementary to chemical methods (Brader, 1975; Lipa, 1964; Niemczyk, 1975). However, all the methods involved in integrated protection should meet standards of modern agriculture; each of them is an extremely important element, and their selection depends on type of cultivated plant as well as on controlled weed species (Olszak et al., 2000).

The introduction of new technologies to herbicide production, which ensures their high effectiveness, in some cases enables a reduction in herbicide doses. Many studies showed the possibility of a reduction in herbicide doses by about 25-40% without a significant decrease in their herbicidal effectiveness and yield reduction (Domaradzki and Rola, 2003; Mitchel, 1998; Salonen, 1992; Talgre et al., 2004; Zhang et al., 2000). Reduced herbicide doses have been successfully used in Europe. It does not result only from concern about threat to environment but also from willingness to cut down on the costs of plant protection (Kudsk and Streibig, 2003). The most important factor which conditions the effect of an herbicide dose is species composition of weeds and their developmental stage. Species named as sensitive on the label of an herbicide can be successfully controlled with herbicide doses lower than recommended (Kudsk, 1989; de Mol et al., 2015).

Received 11 January 2016; accepted 7 February 2017. First online: March, 2017. DII 2067-5720 RAR 2017-8

Researches indicate that regulation of weed infestation depends on the group of cultivated plants. In dense stands, including cereals, total weed control is not always necessary because in that case a reduction in their prevalence by about 80-90% is sufficient. As a result of strong competitive effect, other weeds are suppressed, and their remaining number can not have influence on level of collected yield (Adamczewski and Dobrzański, 1997).

An important element conditioning herbicide effect should also be appropriate selection of cultivars of cultivated plants, characterized by considerable competitive abilities against weeds (Lemerle et al., 1996; Mason et al., 2007; Zerner, 2010). Traits which may influence plant competitiveness are morphological, physiological and biochemical (Lemerle et al., 2001). Authors of many studies demonstrated that competitive abilities of cultivated plants depend on such factors as: plant height, tillering ability, stand structure, light absorption, early biomass accumulation, ground cover, flag leaf length and heading time (Champion et al., 1998; Hucl, 1998; Huel and Hucl, 1996; Korres and Froud-Williams, 2002; Lemerle et al., 1996; Wicks et al., 1986).

While it is known that the cultivar mixtures usually stabilize crops and reduce yield losses caused by diseases (Finckh et al., 2000), their influence on weed infestation has not been adequately investigated. Competitive abilities of different crop cultivars depend on many factors, and knowledge of them may contribute to improvement in competitive abilities against weeds.

Utilization of the potential of crop cultivars combined with other available methods of plant protection, such as a reduction in herbicide doses, may definitely improve effectiveness of weed control programs.

The aim of the present study was to assess competitive abilities of the selected cultivars of spring wheat and their mixtures, taking into account the possibility of application of reduced herbicide doses. In addition, influence of the examined factors on grain yield and on the selected parameters of yield and grain quality was determined.

MATERIAL AND METHODS

Experimental design

Field experiments were carried out in the years 2011 and 2012 in the Field Experimental Station in Winna Góra of the Institute of Plant Protection – National Research Institute, located about 60 km from Poznań (52°12'36"N, 17°26'4"E), Poland. In the first year the experiment was established on gray-brown podzolic soil of pH=5.5 and organic matter content of 1.19%. Mineral fertilization was applied before sowing of the cultivated plant: N=20 kg ha^{-1}, P_2O_5=60 kg ha^{-1}, K_2O=60 kg ha^{-1}, and after wheat seedling emergence: N=0.6 kg ha^{-1}, P_2O_5=0.6 kg ha^{-1}, K_2O=0.6 kg ha^{-1}. In the next year the experiment was located on podzolic soil of pH=6.3 and organic matter content of 1.04%. Before sowing of the cultivated plant, N=16 kg ha^{-1}, P_2O_5=48 kg $ha^{-1}$and K_2O=80 kg ha^{-1} were used, and after wheat seedling emergence – N=102 kg ha^{-1}. Sugar beet was a forecrop in the both years of the research.

Field plots had surface area of 16.5 m^2 (width of 1.5 m, length of 11.5 m), and inter-row spacing was 12.5 cm. Two cultivars of spring wheat were used: Bombona and Waluta, registered in Poland respectively in 2005 and 2008. Spring wheat was sown in the first (2012) and in the second (2011) week of April. Sowing rate was established on the basis of thousand grain weight and germination ability with regarding kernel sowing density of 450 kernels m^{-2} for both cultivars. After calculations, sowing rates were determined for cultivar Bombona respectively for the years of the research – 177.0 kg ha^{-1} (2011) and 189.5 kg ha^{-1} (2012), and for Waluta – 210.0 kg ha^{-1} (2011) and 236.5 kg ha^{-1} (2012). The cultivars of spring wheat were sown individually and in a mixture with a ratio of the cultivars of 50% + 50%.

A mixture of the following substances was used in the experiments: 8.3 g kg^{-1} iodosulfuron-methyl-sodium (triazinylsulfonylurea herbicides) + 140 g kg^{-1} propoxycarbazone-sodium (triazolone herbicides) + 60 g kg^{-1} amidosulfuron (pyrimidinylsulfonylurea herbicides). Also paraffin oil (76%) at dose 1.5 l ha^{-1} was used as adjuvant with reduced herbicide doses.

Active substances – herbicide components, are included in the group of inhibitors of amino acid biosynthesis. Treatments with the herbicide were performed at the tillering of spring wheat (BBCH 22) with a pressure plot sprayer of tank volume of 4 l, working pressure of 0.2 MPa, nozzle spacing of 50 cm, application rate of 200 l ha^{-1}, mounting of sprayer beam of 50 cm and working velocity of 5 km h^{-1}. A control object was used for each of the examined cultivars, where no chemical weed control was implemented.

Analyses and measurements:

Weed infestation

Analysis of weed infestation was conducted with quantitative and weight method within the sample area of each plot determined with a 25 cm x 50 cm frame at two randomly selected sites. Species of the collected weeds were determined then counted, and their fresh weight was assessed. The analysis was carried out 3-4 weeks after the treatment and the obtained results were calculated per surface area of 1 m^2. The results presented in the study on weed number and fresh weight were presented as integers and were given per unit area.

Grain yield, yield parameters, yield qualitative analysis

Spring wheat grain was collected from the area of 16.5 m^2 with a plot combine, and grain yield was determined at 14% grain moisture and then calculated per surface area of 1 ha. Before harvesting of the cultivated plant, 25 wheat ears were collected from each plot and grain number per ear was determined on the basis of threshed sample. Grain sample of 0.5 kg was used to assess thousand kernel weight and to carry out qualitative analysis of grain (content of starch, protein and gluten, Zeleny sedimentation index) with the use of an InfratecTM 1241 Grain Analyzer (FOSS). In addition, bulk density of grain was measured using a precise scale and a grain-weighing machine.

Statistical calculations

The experiment used two factors: herbicide dose and cultivar of spring wheat. Experimental plots were arranged in a randomized block design in four repetitions. The results were subjected to statistical analysis for two-factor experiments, in accordance with experiment model, with the use of FR – ANALWAR – 4.3 software. Significance of differences was assessed with Tukey's confidence half-interval at significance level p=0.05.

RESULTS

Weed infestation

In the years of the research the weed population was predominated by *Chenopodium album* L., accounting for over 87%. Also *Viola arvensis* Murr. was quite numerous (8%), while other species accounted for less than 3%. Accompanying species in the weed population included: *Polygonum convolvulus* L., *Brassica napus* L., *Galium aparine L.*, *Thlaspi arvense* L., *Geranium pusillum* L., *Euphorbia helioscopia* L. and *Stellaria media* (L.) Vill.

On average for the years of the research, both experimental factors (herbicide dose and wheat cultivar) affected weed number and fresh weight per unit area (Table 1). Taking into account the herbicide dose (on average), it can be concluded that each of the used doses caused a significant reduction in weed number and weight. The least number of weeds and their lowest weight were noted in the variants where the herbicide at the decreased dose was used with adjuvant. Among cultivars, the lowest weed number was found for the cultivar mixture, while the lowest weed weight was observed for cultivar Bombona. In both cases (weed number and weight), cultivar Waluta was the most weed-infested. Various influences of the examined factors were noticeable in individual experimental variants. The lowest number and weight of weeds in control variants was found for cultivar Bombona, in the variants where the recommended herbicide dose was used – for the cultivar mixture, and in the variants where the herbicide was applied at the reduced dose with adjuvant – for cultivar Bombona. In the variants where the reduced dose was applied, the lowest number of weeds was noted for cultivar Waluta, while the lowest weed weight was observed for cultivar Bombona. It should also be emphasized that sowing of mixtures of wheat cultivars evidently caused an improvement in mixture competitiveness against weeds. When weed weight was considered, the cultivar mixture exhibited nearly 80% lower weed infestation than cultivar Waluta.

Table 1. Weeds number and weeds fresh weight

Treatment	Rate (g ha^{-1})	Cultivar	Number weeds (no. m^{-2})	Weeds fresh weight (g m^{-2})
Non	0	Bombona	84	59.7
Non	0	Waluta	112	204.6
Non	0	Bombona + Waluta	92	75.2
Iodo + Propo + Amido	2.5 + 42.0 + 18.0	Bombona	70	43.3
Iodo + Propo + Amido	2.5 + 42.0 + 18.0	Waluta	71	129.5
Iodo + Propo + Amido	2.5 + 42.0 + 18.0	Bombona + Waluta	53	38.6
Iodo + Propo + Amido	1.3 + 21.0 + 9.0	Bombona	72	43.8
Iodo + Propo + Amido	1.3 + 21.0 + 9.0	Waluta	77	168.1
Iodo + Propo + Amido	1.3 + 21.0 + 9.0	Bombona +Waluta	73	45.9
Iodo + Propo + Amido (+ Adju)	1.3 + 21.0 + 9.0	Bombona	50	15.6
Iodo + Propo + Amido (+ Adju)	1.3 + 21.0 + 9.0	Waluta	70	89.9
Iodo + Propo + Amido (+ Adju)	1.3 + 21.0 + 9.0	Bombona + Waluta	54	31.1
Average for dose: 0			96	113.2
2,5 + 42,0 + 18,0			65	70.5
1,3 + 21,0 + 9,0			74	85.9
1,3 + 21,0 + 9,0 + adjuvant			58	45.5
Average for cultivar: Bombona			69	40.6
Waluta			83	148.0
Bombona + Waluta			68	47.7
LSD (0.05): factor A[1)]			1.0	3.75
factor B[2)]			0.8	2.95
A(B)[3)]			1.8	6.50
B(A)[4)]			1.6	5.89

Non - nontreated; Iodo - iodosulfuron-methyl-sodium; Propo - propoxycarbazone-sodium; Amido - amidosulfuron; Adju - adjuvant.
[1)] the least significant difference for herbicide dose (A); [2)] the least significant difference for wheat cultivar (B);
[3)]the least significant difference for A and B interaction, for constant B; [4)] the least significant difference for A and B interaction, for constant A.

Grain yield, yield parameters, yield qualitative analysis

Wheat grain yield depended on herbicide dose and examined cultivar (Table 2). Irrespective of wheat cultivar, the highest grain yields were obtained from the variants where the herbicide was used at the reduced dose with adjuvant. However, all the examined herbicide doses differed significantly from the control. In the control and in the variants where the reduced herbicide dose was used (individually and with adjuvant) significantly the highest grain yields were noted for the cultivar mixture. In the variants where the full herbicide dose was applied, the highest yield was noted for cultivar Bombona. The lowest grain yield in the named variants was found for cultivar Waluta. Thousand kernel weight and grain number per wheat ear was affected by the both experimental factors; however, interactions between the factors were not statistically confirmed (Table 2). Taking into account herbicide dose only, it was observed that thousand grain weight and grain number per ear in the variants with the reduced herbicide dose and adjuvant significantly differed from the control.

Table 2. Grain yield, weight of 1000 grains and grain number per ear

Treatment	Rate (g ha^{-1})	Cultivar	Yield (t ha^{-1})	1000 grains weight (g)	Grain number per ear (no.)
Non	0	Bombona	4.2	38.9	38
Non	0	Waluta	3.9	40.5	39
Non	0	Bombona + Waluta	4.4	39.2	41
Iodo + Propo + Amido	2.5 + 42.0 + 18.0	Bombona	5.0	39.6	39
Iodo + Propo + Amido	2.5 + 42.0 + 18.0	Waluta	4.2	43.8	40
Iodo + Propo + Amido	2.5 + 42.0 + 18.0	Bombona + Waluta	4.8	39.9	40
Iodo + Propo + Amido	1.3 + 21.0 + 9.0	Bombona	4.6	39.5	37
Iodo + Propo + Amido	1.3 + 21.0 + 9.0	Waluta	4.1	41.1	41
Iodo + Propo + Amido	1.3 + 21.0 + 9.0	Bombona + Waluta	4.7	40.7	39
Iodo + Propo + Amido (+ Adju)	1.3 + 21.0 + 9.0	Bombona	4.8	40.6	39
Iodo + Propo + Amido (+ Adju)	1.3 + 21.0 + 9.0	Waluta	4.5	43.8	43
Iodo + Propo + Amido (+ Adju)	1.3 + 21.0 + 9.0	Bombona + Waluta	5.0	40.5	42
Average for dose:	0		4.2	39.5	39
	2.5 + 42.0 + 18.0		4.7	41.1	40
	1.3 + 21.0 + 9.0		4.5	40.4	39
	1.3 + 21.0 + 9.0 + adjuvant		4.8	41.6	41
Average for cultivar:	Bombona		4.7	39.7	38
	Waluta		4.2	42.3	41
	Bombona + Waluta		4.7	40.1	41
LSD (0.05):	factor A[1)]		0.03	1.74	2.0
	factor B[2)]		0.02	1.37	1.5
	A(B)[3)]		0.04	n.s.	n.s.
	B(A)[4)]		0.04	n.s.	n.s.

n.s. - not significant difference.

Table 3. Content of protein, starch, gluten, zeleny index and grain bulk density

Treatment	Rate (g ha^{-1})	Cultivar	Protein (%)	Starch (%)	Gluten (%)	Zeleny	Grain bulk density (kg hl^{-1})
Non	0	Bombona	13.0	69.1	30.6	42.2	77.4
Non	0	Waluta	11.6	70.3	27.1	32.8	78.2
Non	0	Bombona + Waluta	12.5	69.4	29.7	39.8	78.0
Iodo + Propo + Amido	2.5 + 42.0 + 18.0	Bombona	13.8	68.2	33.5	47.1	77.8
Iodo + Propo + Amido	2.5 + 42.0 + 18.0	Waluta	12.7	69.2	30.1	38.9	78.7
Iodo + Propo + Amido	2.5 + 42.0 + 18.0	Bombona + Waluta	12.9	69.1	31.0	42.3	78.6
Iodo + Propo + Amido	1.3 + 21.0 + 9.0	Bombona	13.7	68.1	33.6	47.8	78.1
Iodo + Propo + Amido	1.3 + 21.0 + 9.0	Waluta	12.5	69.3	29.8	38.7	78.7
Iodo + Propo + Amido	1.3 + 21.0 + 9.0	Bombona + Waluta	13.3	68.6	31.9	44.6	78.3
Iodo + Propo + Amido (+ Adju)	1.3 + 21.0 + 9.0	Bombona	13.9	67.9	34.0	48.3	77.8
Iodo + Propo + Amido (+ Adju)	1.3 + 21.0 + 9.0	Waluta	13.1	68.7	31.7	42.7	79.0
Iodo + Propo + Amido (+ Adju)	1.3 + 21.0 + 9.0	Bombona + Waluta	13.4	68.7	32.7	45.6	78.7
Average for dose:	0		12.4	69.6	29.1	38.3	77.9
	2.5 + 42.0 + 18.0		13.1	68.8	31.5	42.8	78.4
	1.3 + 21.0 + 9.0		13.2	68.7	31.8	43.7	78.4
	1.3 + 21.0 + 9.0 + adjuvant		13.5	68.4	32.8	45.5	78.5
Average for cultivar:	Bombona		13.6	68.3	32.9	46.4	77.8
	Waluta		12.5	69.4	29.7	38.3	78.7
	Bombona + Waluta		13.0	69.0	31.3	43.1	78.4
LSD (0.05):	factor A[1)]		0.56	0.60	1.76	4.01	0.47
	factor B[2)]		0.44	0.47	1.39	3.15	0.37
	A(B)[3)]		n.s.	n.s.	n.s.	n.s.	n.s.
	B(A)[4)]		n.s.	n.s.	n.s.	n.s.	n.s.

n.s. - not significant difference.

The examined experimental factors had influence on the selected parameters of grain quality, while no interaction was found between the factors (Table 3). The lowest content of protein and gluten was noted in grains from the control. However, no differences were observed between herbicide doses. The highest content of starch and gluten was found in cultivar Waluta, while the highest content of protein was observed in Bombona. Zeleny index for all the variants where the herbicide was applied was higher when compared to the control, while significant differences in grain bulk density were noted between the control and the variant where the reduced dose of the herbicide was applied with adjuvant.

DISCUSSION

Satisfactory effectiveness of reduced herbicide doses was observed also in experiments by other authors (Boström and Fogelfors, 2002; Domaradzki, 2003; Steckel et al., 1990; Zhang et al., 2000). Success of application of reduced herbicide doses depends on time of herbicide application and weed species in a field, which was proved by Barros et al. (2007). The authors demonstrated that effectiveness of the reduced herbicide doses against monocotyledonous weeds (*Avena sterilis* L. and *Lolium rigidum* G.) was better than against some dicotyledonous weeds. Experiments carried out by O'Donovan et al. (2007) demonstrated that an increase in plant competitiveness by cultivation of competitive cultivars with simultaneous increasing sowing rate and appropriate fertilization strategy may reduce influence of weeds on yielding and decrease the soil weed seed bank. Differences in competitiveness of cereal cultivars were confirmed also by Mennan and Zandstra (2005) for biomass and seed number of *Galium aparine* L. and by Tanner et al. (1995) for *Avena fatua* L. In the present research, addition of adjuvant significantly affected herbicidal effectiveness of the reduced herbicide dose (Table 1). Positive influence of adjuvants on herbicide effectiveness was confirmed by Kwiatkowski and Wesołowski (2011) and Idziak et al., 2013, while Zhang et al. (2000) stated that the success of reduced doses is irrespective of herbicide application in the conventional or reduced system, or of herbicide application together with adjuvants. Factors which affect the competitive abilities of cultivars of cultivated plants against weeds include e.g. plant height (Kraska, 2006; Roberts et al., 2001), but also great importance of the phenomenon of allelopathy has been emphasized (Bertholdsson, 2012; Mardani and Yousefi, 2012; Wu et al., 2002). Influence of plant height on competitiveness has been confirmed also in previous own research on winter wheat (Kaczmarek et al., 2009). The experiments described in the present study were on cultivars of spring wheat not differing significantly in plant height.

Numerous herbicide molecules at lower doses than recommended exhibit herbicidal effectiveness which ensures obtaining high yield and also does not cause an increase in weed infestation in the following year (Khalid et al., 2011; Sheikhhasan et al., 2012; Zhang et al., 2000). For instance, a study on wheat (Sheikhhasan et al., 2012) demonstrated the possibility of a reduction in the use of substances sulfosulfuron and sulfosulfuron + metsulfuron (80% of the recommended dose) without a significant yield reduction; additionally, a reduced herbicide dose did not adversely affect grain number per ear and thousand grain weight of wheat. Buczek et al. (2012) and Kwiatkowski et al. (2011) presented various effect of reduced herbicide doses on qualitative parameters of cereal grain. Kwiatkowski et al. (2011) found that the reduction of pesticide doses, in spite of interaction with adjuvants, had negative effect on the content of the analyzed nutrients in the grain. Buczek et al. (2012) proved that it was possible to reduce herbicide dose used on the winter wheat field at least 25% without considerable yield decrease; moreover results indicated that the protein content, sedimentation index and 1000 grains weight considerably increased as a result of fertilizer application, recommended and reduced herbicide dose.

In summary it can be concluded that variety Bombona was characterized by the lowest weeds expressed in weight of weeds. Weight of weeds for this variety was more than 70% lower in comparison with Waluta variety. Each of the tested herbicide dose increased grain yield of spring wheat, the highest yield being noticed on the plot where herbicide was applied at reduced dose with adjuvant. Both experimental factors (the wheat variety and the herbicide dose) affected quantitative and qualitative parameters (grain number per ear, thousand grain weight, content of protein, starch and gluten, Zeleny sedimentation index, grain bulk density).

CONCLUSION

Wheat cultivars and doses of iodosulfuron-methyl-sodium, propoxycarbazone-sodium, amidosulfuron determine the level of weed control under field conditions.

REFERENCES

Adamczewski, K., Dobrzański, A., 1997. *Weed control management in integrated crop production*. Prog. Plant Prot./Post. Ochr. Roślin, 37(1): 58-65.

Barros, J.F.C., Basch, G., Varvalho, M., 2007. *Effect of reduced doses of a post-emergence herbicide to control grass and groad-leaved weeds in no-till wheat under Mediterranean conditions*. Crop Prot., 26: 1538-1545.

Bertholdsson, N-O., 2012. *Allelopathy – a tool to improve the weed competitive ability of wheat with herbicide-resistant black-grass* (*Alopecurus mysouroides Huds.).* Agronomy, 2: 284-294. DOI:10.3390/agronomy2040284

Boström, U., Fogelfors, H., 2002. *Response of weeds and crop yield to herbicide dose decision-support guidelines*. Weed Sci., 50: 186-195

Brader, L., 1975. *Integrated control a new approach in crop protection.* 5th Symp. Lutte intègrèe en verges, OILB/SROP, Bolzano: 9-16.

Buczek, J., Tobiasz-Salach, R., Bobrecka-Jamro, D., 2012. *Influence of foliar application of fertilizers and of lower doses of herbicide on yields and quality of grains of winter wheat*. Fragm. Agron., 29(1): 7-15.

Champion, G.T., Froud-Williams, R.J., Holland, J.M., 1998. *Interactions between wheat (Triticum aestivum L.) cultivar, row spacing and density and the effect on weed suppression and crop yield*. Ann. Appl. Biol., 133: 443-453.

de Mol, F., Gerowitt, B,, Kaczmarek, S., Matysiak, K., Sønderskov, M., Mathiassen, S.K., 2015. *Intraregional and inter-regional variability of herbicide sensitivity in common arable weed populations.* Weed Res., 55: 370-379.

Domaradzki, K., 2003. *Weed control in spring cereals by lower doses of herbicides*. J. Plant Prot. Res., 43(3): 247-254.

Domaradzki, K., Rola, H., 2003. *The possibility of weed control in cereals by use low rates of herbicides – review of existing investigations.* J. Plant Prot. Res., 43(2): 163-170.

Hucl, P., 1998. *Response to weed control by four spring wheat genotypes differing in competitive ability.* Can. J. Plant Sci., 78: 171-173.

Huel, D.G., Hucl, P., 1996. *Genotypic variation for competitive ability in spring wheat*. Plant Breeding, 115: 325-329.

Idziak, R., Woźnica, Z., Sobiech, Ł., (2013). *Effect of oil and mineral adjuvants on efficacy and physic-chemical properties of foramsulfuron and iodosulfuron spry mixture*. Pak. J. Agri. Sci., 50(4): 671-676.

Kaczmarek, S., Kierzek, R., Gruchot, D., 2009. *Winter wheat response to application of reduced doses of fluroxypyr + 2,4 D.* Bull. Inst. Plant Breed. Acclim., 254: 13-20.

Khaliq, A., Matloob, A., Tanveer, A., Areeb, A., Aslam, F., Abbas N., 2011. *Reduced doses of sulfonylurea herbicide for weed management in wheat fields of Punjab, Pakistan.* Chil. J. Agr. Res., 71(3): 22-27.

Korres, N.E., Froud-Williams, R.J., 2002. *Effects of winter wheat cultivars and seed rate on the biological characteristics of naturally occurring weed flora.* Weed Res., 42: 417-428.

Kraska, P., 2006. *The influence of different herbicides doses on winter wheat weed infestation.* Prog. Plant Prot./Post. Ochr. Roślin, 46: 256-260.

Kudsk, P., Streibig, J.C., 2003. *Herbicides – a two-edged sword.* Weed Res., 43: 90-102.

Kudsk, P., 1989. *Experiences with reduced herbicide doses in Denmark and the development of the concept of factor-adjusted doses.* Proc. Brighton Crop Prot. Conf. Weeds, 4: 545-554.

Kwiatkowski, C.A., Wesołowski, M., 2011. *Effect of adjuvants and reduced doses of pesticides on weed infestation in winter wheat.* Prog. Plant Prot./Post. Ochr. Roślin, 51(1): 348-353.

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

Lemerle, D., Verbeek, B., Coombes, N.E., 1996. *Interaction between wheat (Triticum aestivum) and diclofop to reduce the cost of annual rygrass (Lolium rigidum) control.* Weed Sci., 44: 634-639.

Lemerle, D., Gill, G.S., Murphy, C.E., Walker, S.R., Cousens, R.D., Mokhtari, S., Peltzer, S.J., Coleman, R., Luckett, D.J., 2001. *Genetic improvement and agronomy for enhanced wheat competitiveness with weeds.* Aust. J. Agric. Res., 52: 527-548.

Lipa, J.J., 1964. *Integration of chemical and biological control in plant protection.* Post. Nauk Roln., 1: 55-72.

Mardani, R., Yousefi, A.R., 2012. *Using image analysis to study the allelopathic potential of wheat cultivars against wild barley (Hordeum spontaneum).* Intl. Res. J. Appl. Basic. Sci., 3(11): 2281-2288.

Mason, H.E., Navabi, A., Frick, B.L., O'Donovan, J.T., Spaner, D.M., 2007. *The weed-competitive ability of Canada western red spring wheat cultivars grown under organic management.* Crop Sci., 47: 1167-1176.

Mennan, H., Zandstra, B.H., 2005. *Effect of wheat (Triticum aestivum) cultivars and seeding rate on yield loss from Galium aparine (cleavers).* Crop Prot., 24: 1061-1067.

Mitchell, B.J., 1998. *Reduced herbicide inputs In cereals. Report, Crop Research Centre, Oak Park, Carlow.* (www.teagasc.ie/research/reports/crops/4136/eopr-4136.htm)

Niemczyk, E., 1975. *Integrated control in orchards in Poland.* 5th Symp. Lutte intègrèe en verges, OILB/SROP, Bolzano: 97-98.

O'Donovan, J.T., Blackshaw, R.E., Harker, K.N., Clayton, G.W., Moyer J.R., Dosdall, L.M., Maurice, D.C., Turkington, T.K., 2007. *Integrated approaches to managing weeds in spring-sown crops in western Canada.* Crop Prot., 26: 390-393.

Olszak, R.W., Pruszyński, S., Lipa, J.J., 2000. *Development of the concepts and strategies of plant protection – methods and means.* Prog. Plant Prot./Post. Ochr. Roślin, 40: 40-50.

Roberts, J.R., Peeper, T.F., Solie, J.B., 2001. *Wheat (Triticum aestivum) row spacing, seeding rate and cultivar affect interference from rye (Secale cereale).* Weed Technol., 15: 19-25.

Salonen, J., 1992. *Yield response of spring cereals to reduced herbicide doses.* Weed Res., 32: 493-499.

Sheikhhasan, M.R.V., Mirshekari, B., Farahvash, F., 2012. *Weed control in wheat fields by limited dose of post-emergence herbicides.* World Appl. Sci. J., 16(9): 1243-1246.

Steckel, L.E., DeFelice, M.S., Sims, B.D., 1990. *Integrating reduced doses of post emergence herbicides and cultivation for broadleaf weed control in soybeans (Glycine max).* Weed Sci., 38: 541-545.

Stern, V.M., Smith, R.F., van den Bosch, R., Hagen, K.S., 1959. *The integration of chemical and biological control of the spotted alfalfa aphid. Part I. The integrated control concept.* Hilgardia, 29: 81-101.

Stern, V.M., 1973. *Economic thresholds.* Ann. Rev. Ent., 18: 259-280.

Talgre, L., Lauringson, E., Koppel, M., Nurmekivi, H., Sulev, U., 2004. *Weed control in spring barley by lower doses in Estonia.* Agronomijas Vestis LLU, 7: 171-175.

Tanner, D.G., Sahile, G., Tilahun, W., 1995. *Competitive ability of Ethiopian spring bread wheat cultivars with Avena fatua L.* Afr. Crop Sci. J., 3(1): 83-91.

Wicks, G.A., Ramsel, R.E., Nordquist, P.T., Schmidt, J.W., Challaiah, R.E., 1986. *Impact of wheat cultivars on establishment and suppression of summer annual weeds.* Agron. J., 78: 59-62.

Wu, H; Pratley, J; Lemerle, D; Haig, T., 2002. *Crop cultivars with allelopathic capability.* Weed Res., 39: 171-180.

Zerner, M., Gill, G., 2010. *Stability of competitive ability in wheat genotypes across different weed species.* "Food Security from Sustainable Agriculture" Edited by H. Dove and R.A. Culvenor, Proceedings of 15th Agronomy Conference, 15-18 November 2010, Lincoln, New Zealand. http://www.regional.org.au/au/asa/2010/crop production/weeds/7037_zernerm.htm

Zhang, J., Weaver, S.E., Hamill, A.S., 2000. *Risks and reliability of using herbicides at below-labeled rates.* Weed Technol., 14: 106-115.