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IMPACT OF HERBICIDAL ACTIVE SUBSTANCES ON WEED CONTROL IN FACULTATIVE WHEAT

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ABSTRACT

Background. In an integrated wheat production, in simplified crop rotation (winter wheat – facultative wheat) effective solutions should be sought based on total and selective herbicides in weed control.
Material and methods. In a field experiment carried out in the years 2010–2014, the effect of autumn application of glyphosate was investigated, as well as of various active substances in selective herbicides used in spring on the number and weight of mono- and dicotyledonous weeds in the cultivation of spring wheat cv. Monsun sown as facultative wheat.
Results. The spectrum of weed species occurring over the years of research was determined, as well as herbicidal effectiveness of glyphosate and chosen selective herbicides. The highest reduction in the number of dicotyledonous weeds was observed after spring application of tribenuron-methyl, tifensulfuron-methyl with chlorosulfuron, as well as diflufenican and isoproturon. Reduction in the biomass of dicotyledonous weeds for particular variants was: 96% – Chisel 75 WG, 95% – Helmstar 75 WG, 93% – Legato Plus 600 SC, 78% – Chwastox Extra 300 SL + Apyros 75 WG and 68% Starane Super 101 SE + Apyros 75 WG, respectively. Application of glyphosate in the autumn before sowing facultative wheat contributed to a three-fold reduction in the number of monocotyledonous weeds, and in their biomass in the cultivation of wheat cv. Monsun.
Conclusion. In order to achieve the best result of reducing weeds in the cultivation of spring wheat in late--autumn sowing, after cereal forecrop, glyphosate should be applied to autumn crops, and in the spring a suitable herbicide should be selected for the spectrum of the occurring weeds, which contains at least two active substances, e.g. tifensulfuron-methyl with chlorosulfuron or diflufenican with isoproturon.

Key words: facultative wheat, herbicidal active substances, selective herbicide, total herbicide, weed control

INTRODUCTION

The results of cultivating various wheat cultivars are to a large extent dependent on the effectiveness of the conducted weed control methods, which have a decisive influence on the height of the obtained grain yields (Baghestani *et al*., 2007b; Kieloch and Weber, 2013; Sonderskov *et al*., 2015). The greatest threat to wheat, also including facultative cultivars, pose above all the following species: *Viola arvensis*, *Centaurea cyanus*, *Papaver rhoeas*, *Matricaria indora*, *Anthemis arvensis*, *Galium aparine*, *Stellaria media*, *Veronica* sp., *Apera spica-venti*, *Alopecurus myosuroides*, *Avena fatua* (Wysmułek and Ciesielska, 2012; Rola *et al*., 2013; Buczek *et al*., 2014; Kieloch, 2014; Miklaszewska and Kierzek, 2014).

The most effective method of weed control in wheat is the chemical method, involving application

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of various herbicides against dicotyledonous weeds (amidosulfuron, 2,4-D, MCPA, florasulam, fluroxypyr, dicamba, mecoprop, tifensulfuron-methyl, tribenuron), against monocotyledonous weeds (fenoxaprop-P-ethyl, pinoxaden, propoxycarbazone), or aginst various spectrum of mono- and dicotyledonous species (diflufenican, flufenacet, mezosulfuron, pendimethalin). Very often, these substances must be combined to provide an effective weed control of diversified weed communities (Baghestani *et al*., 2007a, c; 2008). The effective weed control is also provided by the application of, particularly in reduced tillage, non-selective herbicides (Calado *et al*., 2010).

In the regulation of weed infestation it is important to suit the selection of active substances in herbicides and their rates to weed infestation occurring on the field, which is also determined by the time of sowing (Ozturk *et al*., 2006; Urban and Kazikowski, 2014), or by plant density in wheat (Olsen *et al*., 2006; Buczek *et al*., 2012). In a large number of situations, keeping the wheat stand clean is possible with an application of reduced herbicide rates (Buczek *et al*., 2012; Urban and Kazikowski, 2014), especially with adjuvants added to the spray liquid (Kucharski *et al*., 2012; Domaradzki, 2013; Miklaszewska and Kierzek, 2014).

Keeping wheat stands clean through the application of herbicides provides a high level of wheat yield (Sullivan *et al*., 2013; Hamouz *et al*., 2015). However, environmental considerations and sometimes the negative effect on crop plants (Soltani *et al*., 2006; Sikkema *et al*., 2007; Kieloch and Sumisławska, 2012) require the use of the chemical method in moderation, and thus an integrated plant protection (Locke *et al*., 2002; Bajwa, 2014), which includes preventive measures (Blackshaw *et al*., 2006; Adamczewski and Dobrzański, 2012;), mechanical methods and others (Kapeluszny *et al*., 2012; Buczek *et al*., 2013), so as to provide sustainable agricultural development (Chauhan *et al*., 2012; Nichols *et al*., 2015). Research hypothesis assumed that the effect of reducing weed infestation in the cultivation of spring wheat sown in late autumn depends on the type of the used chemical substance, and on the time of herbicide application.

The aim of the conducted research was assessment of the effectiveness of various active substances in selective herbicides under conditions of applying a non-selective herbicide in weed control of spring wheat sown in late autumn.

MATERIAL AND METHODS

The studies were carried out at the Research Station of the Faculty of Agriculture and Biotechnology, property of the University of Science and Technology (UTP) in Bydgoszcz, based on a field two-factor experiment in a split-block design, in 4 replications over the years 2010–2014. The experiment included 48 plots with an area of a single plot being 36 m^2. In the experiment, the effect of applying glyphosate, as well as various active substances in selective herbicides was investigated on the damage in weeds, their number and weight in the cultivation of spring wheat cv. Monsun sown as facultative wheat.

The first experimental factor (A) was weed control during post-harvest cultivation:

R – glyphosate (Roundup Energy 450 SL at a rate of 3.0 $dm^3 \cdot ha^{-1}$) applied on stubble field,

B – control – without glyphosate.

The second factor (B) was an active substance in selective herbicides, which were used on weeds according to recommendations:

B1 – control – without herbicide,

B2 – MCPA (Chwastox Extra 300 SL 1.5 $dm^3 \cdot ha^{-1}$) + sulfosulfuron (Apyros 75 WG 15 $g \cdot ha^{-1}$) + adjuvant Trend 90 EC, at the stage 25–29 BBCH,

B3 – fluoxypyr and florasulam (Starane Super 101 SE 1 $dm^3 \cdot ha^{-1}$) + sulfosulfuron (Apyros 75 WG 15 $g \cdot ha^{-1}$) + adjuvant Trend 90 EC, at the stage 25–29 BBCH,

B4 – diflufenican and isoproturon (Legato Plus 600 SC 1.25 $dm^3 \cdot ha^{-1}$), at the stage 13–15 BBCH,

B5 – tifensulfuron-methyl and chlorosulfuron (Chisel 75 WG 40 $g \cdot ha^{-1}$) + adjuvant Trend 90 EC, at the stage 23–25 BBCH,

B6 – tribenuron-methyl (Helmstar 75 WG 25 $g \cdot ha^{-1}$) + adjuvant Trend 90 EC, at the stage 25–29 BBCH.

In total, the experiment included 12 experimental plots, which were combinations of levels of both these factors.

The experiment was carried out on the soil of a good rye complex, bonitation class III b. The forecrop for facultative wheat was winter wheat (2010–2011, 2011–2012, 2012–2013) or winter triticale (2013–2014).

In the autumn, skimming was carried out with a skimming unit. Sow-ploughing was carried out one month before seeding. Fertilization with phosphorus and potassium was applied in a single rate before sowing wheat at the following rates: P – 21.8 kg·ha^{-1}, K – 66.4 kg·ha^{-1}. Nitrogen fertilization was applied in three divided rates. The first rate was applied before sowing at the amount of 30 kg N·ha^{-1}. Two subsequent nitrogen rates were spread in the spring at the amount of 50 kg·ha^{-1} at the start of vegetation, and 30 kg·ha^{-1} at the stage 33 BBCH.

In order to control fungal diseases, grain used for sowing was dressed with a mixture of triadimenol, imazalil and fuberidazole, contained in the commercial product Baytan Universal 094 FS at a rate of 200 g·100 kg^{-1}. Also a fungicide Fandango 200 EC (fluoxastrobin and prothiocona-zole) was applied at a rate of 1 dm^3·ha^{-1} at the stage T2 (41–65 BBCH) in order to protect the base of stem, leaves and spike. All treatments of chemical protection were carried out with the use of a field sprayer Pilmet 412LM, with liquid expenditure of 300 l per ha.

The grain was harvested with a combine harvester at the stage of full maturity. Characteristics of field treatments and observations are presented in Table 1. Field studies with herbicides concerned evaluation of the effectiveness of various active substances on mono- and dicotyledonous weed species. The range of research included assessment of the occurrence of mono- and dicotyledonous weed species, measuring the number of weeds with a square-frame method. In order to do this, a frame of the dimensions 100 cm × 200 cm was placed on each plot, inside of which weeds belonging to particular species were counted. The measurement was carried out in the milk-dough stage in wheat (BBCH 75–85) on control plots in order to make a list of all possible species. Weed plants in frames were cut right at the soil surface, sorted into particular species, dried at a temperature of 22°C, and weighed.

Data concerning the number of weeds per unit of area and their air dry mass were subjected to a test towards normal distribution with the use of Shapiro--Wilk test. Statistical analyses for the data: two-way ANOVA for the split-plot design in each year of research as well as synthesis for the data from the years, after which Tukey's *post-hoc* HSD test was conducted for means within main effects and significant interactions on the level of $P < 0.05$. Calculations were carried out in the program Statistica 12.0, StatSoft, Poland.

Table. 1. Schedule of plant protection treatments against weeds

Season	Date				
	sowing	treatment with glyphosate	treatment with selective herbicides	assessment of damage occurrence in weeds	assessment of weed occurrence
2010/2011	22.11.2010	13.09.2010	12.04.2011 20.05.2011	27.05.2011	12.07.2011
2011/2012	27.10.2011	05.09.2011	disqualification of the experiment after winter		
2012/2013	19.11.2012	23.09.2012	18.04.2013 15.05.2013	25.05.2013	16.07.2013
2013/2014	19.11. 2013	25.09.2013	24.04.2014 12.05.2014	20.05.2014	10.07.2014

RESULTS AND DISCUSSION

Spectrum of weed species occurring in the years of research and herbicidal effectiveness of studied herbicides

The spectrum of weed species was studied each year at the milk-dough stage in grains (BBCH 75–85). In that stage it was also possible to take into consideration secondary weed infestation. In the growing season 2010–2011 the predominant species from the class of dicotyledonous weeds was *Viola arvensis*, which outside the control plot, regardless of glyphosate, occurred in a large number on the plot protected with herbicides Chwastox Extra 300 SL and Apyros 75 WG (85 plants·m^{-2} – without glyphosate and 117 plants·m^{-2} with glyphosate). Combination of Starane Super 101EC and Apyros 75 WG also poorly controlled *Viola arvensis*, its number was 118 plants·m^{-2} on the plot which was not protected with glyphosate (Table 2). Most weeds of other species also occurred on these two experimental plots in 2011. However, some of them were only observed on the control plot, and they included: *Convolvulus arvensis*, or *Equisetum arvense*. From the class of monocotyledonous plants, the predominant species in season 2010–2011 was *Poa annua* occurring on the control plot in both variants with glyphosate and without glyphosate, as well as *Apera spica-venti* also predominant on the control plots. Their total elimination was observed under the effect of herbicide Legato Plus 600 SC and Chisel 75 WG. While Chwastox Extra 300 SL and Starane Super 101 EC, which were applied along with preparation Apyros 75 WG, did not control these two grass species (Table 2). In the research period 2012–2013, the number of species occurring on the plantation of wheat cv. 'Monsun' at the Research Station in Mochełek was higher than in the period 2010–2011, which resulted from the selection of the stand, where wheat was growing in the forecrop for 3 years. In this habitat, there occurred compensation of some species, such as: *Viola arvensis*, *Chenopodium album*, *Cirsium arvense* and *Veronica* sp., as well as *Echinochloa cruss-galli*. These two latter species occurred as secondary weed infestation (Table 2). Compared with the control without herbicides, visibly lower qualitative and quantitative spectrum was observed on all protected plots, and more effectively than in the previous season on the plot protected with preparations Chwastox Extra 300 SL + Apyros 75 WG and Chisel 75 WG. In the growing season 2013-2014, 14 species from the class of dicotyledonous weeds were observed as well as 3 species from the monocotyledonous class. In terms of a lower number of species, it is a different season from the first two research years, which undoubtedly results from the selection of the stand, on which there was no compensation of weeds typical for wheat. The predominant weed was *Viola arvensis*, which was not eliminated by glyphosate on the control plot without herbicides. Herbicide which reduced the number of *Viola arvensis* slightly better than others is Starane Super 101 EC + Apyros 75 WG. With regard to other weed species it may be stated that they all emerged later, as secondary weed infestation, as their intensification was relatively uniform on the control plot and on protected plots, however on control plots the number of species outweighed (Table 2). The studies of Brzozowska and Brzozowski (2012) indicated that in the cultivation of winter wheat, in each year of research there prevailed: *Viola arvensis* and *Veronica arvensis*, moreover there occurred variation in predominant species: in the first year *Capsella bursa-pastoris*, *Stellaria media,* and in the second year *Matricaria maritima*, *Myosotis arvensis* and *Galium aparine*. It was also confirmed in our studies that weed species composition is subjected to seasonal variation, which is affected by habitat conditions, especially the abundance of seeds in the soil (Adamczewski and Praczyk, 1999). The level of weed infestation, and consequently the selection of herbicides for weed control, is also affected by the course of meteorological conditions, affecting the dynamics of weed emergence, as well as the condition of wheat and its ability to compete with segetal flora (Ozturk *et al*., 2006; Urban and Kazikowski, 2014). The most numerously occurring and the most representative species in winter wheat cultivation is *Apera spica venti*, which occurs in all experiments carried out by Idziak *et al.,* (2012) on average at a rate of 67 plants per m^2. Less numerously there occurred: *Viola arvensis* and *Galium aparine*, at an average intensification of 26 and 23 plants per m^2. At a lower intensification (11–14 plants per m^2) there occurred: *Capsella bursa-pastoris, Stellaria media* and *Brassica napus*. At an average number (8–10 plants per m^2), though with a lower frequency of occurrence on plantations of winter wheat, there occurred such species as: *Matricaria inodora*, *Myosotis arvensis*, *Papaver rhoeas*, *Veronica* sp. and *Lamium* sp. Our research results confirm previous reports concerning the positive effect of a combined application of several active substances on expanding the spectrum of the controlled weed species, as well as on the improvement in herbicidal effectiveness compared with the species considered as resistant. Kierzek and Urban (2006) indicated that application of a mixture containing MCPA, dicamba and diflufenican also contributed to an improvement in herbicidal effectiveness compared with the species considered as resistant (*G. aparine*, *V. arvensis*, *L. purpureum*, *P. convolvulus*).

Table 2. Spectrum of weed species and their number per 1 m^2 occurring on the plantation of wheat cv. 'Monsun' at late-autumn date of sowing in the years of research

Specification		B1**		B2		B3		B4		B5		B6	
		R*	B#	R	B	R	B	R	B	R	B	R	B
Dicotyledonous species													
Centaurea cyanus L.	2011			1	1								
	2013												
	2014												
Viola arvensis Murr.	2011	194	169	117	85	12	118	1					
	2013	15	16	14	2	13	15	1	12	7	5	5	6
	2014	120	89	78	69	36	5	21	17	51	32	39	5
Sinapis arvensis L.	2011	7	14	5	52	2	1				1		1
	2013												
	2014												
Stellaria media L.	2011				1		1						
	2013		1										
	2014												
Chenopodium album L.	2011	21	29	2	3	22	14		1				
	2013	29	36	1	2	12	13		1			1	1
	2014	7		1	1	7	14			1	1		
Papaver rhoeas L.	2011	1	1										
	2013												
	2014	3	2										
Matricaria indora L.	2011	11	16	8	22	7	15						
	2013	1	1	1	1								
	2014	2	12	4	1						3		
Myosotis arvensis L.	2011	4	1	2	2	5	1				2		
	2013												
	2014												

Table 2 continue

Specification		B1**		B2		B3		B4		B5		B6	
		R*	B#	R	B	R	B	R	B	R	B	R	B
Cirsium arvense L.	2011				2	3	2				4		
	2013	3	2				4		1	1	1		1
	2014												
Convolvulus arvensis L.	2011		2										
	2013												
	2014												
Galium aparine L.	2011	1											
	2013		1		1				1	1	1		
	2014												
Polygonum lapathifolium L.	2011		1										
	2013	1		1		1							
	2014												
Fallopia convolvulus L.	2011	4	7										
	2013	2	2	1	2							7	3
	2014		12										
Polygonum aviculare L.	2011	11	14	3	7	2	1	12				4	2
	2013	3	4	3	1				1				
	2014	2	1		1				1			3	1
Equisetum arvense L.	2011	124	12					2				11	
	2013												
	2014												
Amaranthus retroflexus L.	2011				1								
	2013												
	2014												
Thlaspi arvense L.	2011	44	24	3	7	12	6			1			
	2013	4	9										
	2014	1	2	4	4	7	2	3	1	1		1	
Capsella bursa pastoris L.	2011		1			1							
	2013	1									1		
	2014												
Galinsoga parviflora Cav.	2011				1								
	2013	1	3		1								
	2014												
Plantago major L.	2011												
	2013	1	1			3	2		1				2
	2014												

Table 2 continue

Specification		B1**		B2		B3		B4		B5		B6	
		R*	B#	R	B	R	B	R	B	R	B	R	B
Geranium pusillum L.	2011												
	2013	4	6	1	2		1	3	2			1	2
	2014										1		
Artemisia vulgaris L.	2011												
	2013												1
	2014		1										
Lamium amplexicaule L.	2011												
	2013	1			1			1	1				
	2014				1			2	1		1		
Taraxacum officinale Weber	2011												
	2013		1		1								
	2014												
Silybum marianum L.	2011												
	2013				1	1	3	3	2	1	2	5	2
	2014												
Veronica chamaedrys L.	2011												
	2013	1			1			4		1			
	2014												
Veronica persica Poir.	2011												
	2013		1	1		1		1	1			1	3
	2014												
Anthemis arvensis L.	2011												
	2013			1								1	
	2014												
Veronica arvensis L.	2011												
	2013												
	2014	5	2	8	1	1	8	2	4	3	2	3	7
Veronica hederifolia L.	2011												
	2013												
	2014							1		2	1	2	
Plantago lanceteolata L.	2011												
	2013												
	2014							1		2			1
Conyza canadensis L.	2011												
	2013												
	2014	1											

Table 2 continue

Specification		B1**		B2		B3		B4		B5		B6	
		R*	B#	R	B	R	B	R	B	R	B	R	B
Monocotyledonous species													
Apera spica venti L.	2011	7	8	1	4	4	2						
	2013		1						1				
	2014	2	2	3	2			2	2				
Poa annua L.	2011	3	5	4	1	2	1					1	1
	2013		2	3	3	2	3	4	3	4	2	13	1
	2014	1	2	1	2	2	2	1	4	7	6	2	7
Avena fatua L.	2011												
	2013												
	2014	2	1		1								
Echinochloa cruss galli L.	2011												
	2013	11	77	32	17	8	34	27	87	18	92	21	216
	2014												

*R – Roundup Energy 450 SL 3.0 $dm^3 \cdot ha^{-1}$; #B – without glyphosate; ** B1 – control, B2 – Chwastox Extra 300 SL (MCPA) 1.5 $dm^3 \cdot ha^{-1}$ + Apyros 75 WG (sulfosulfuron) 15 $g \cdot ha^{-1}$ + Trend 90 EC (adjuvant), B3 – Starane Super 101 SE (fluoxypyr and florasulam) 1 $dm^3 \cdot ha^{-1}$ + Apyros 75 WG (sulfosulfuron) 15 $g \cdot ha^{-1}$ + Trend 90 EC (adjuvant), B4 – Legato Plus 600 SC (diflufenican and isoproturon) 1.25 $dm^3 \cdot ha^{-1}$, B5 – Chisel 75 WG (thifensulfuron-methyl and chlorosulfuron) 40 $g \cdot ha^{-1}$ + Trend 90 EC (adjuvant), B6 – Helmstar 75 WG (tribenuron-methyl) 25 $g \cdot ha^{-1}$ + Trend 90 EC (adjuvant)

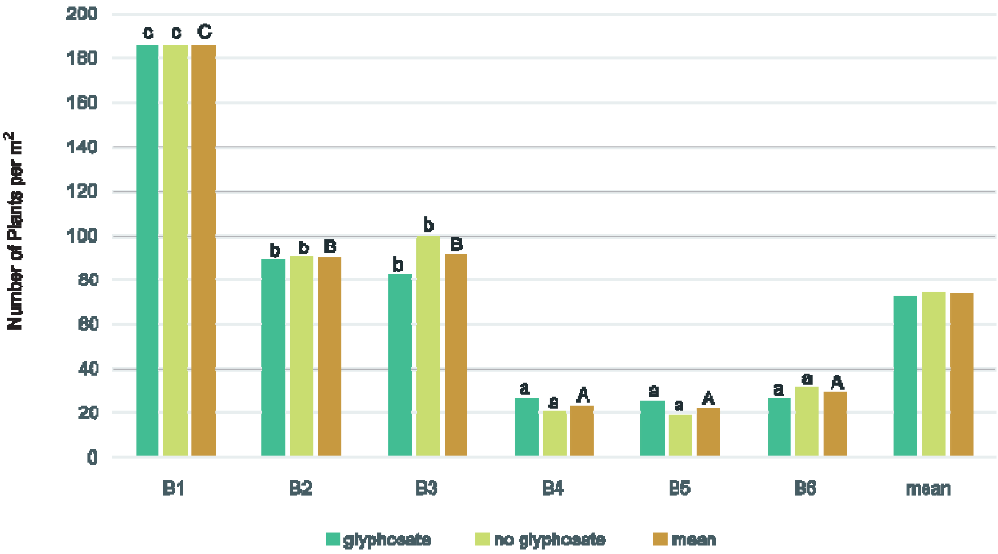
Analysis of the number and air dry mass of dicotyledonous weeds

In the synthesis from the three years, a significant effect of spring application of herbicides was obtained on reducing the number of dicotyledonous weeds. Under the effect of the three active substances applied on foliage, i.e. tribenuron-methyl, in preparation Helmstar 75 WG, thifensulfuron-methyl with chloro--sulfuron (preparation Chisel 75 WG), as well as diflufenican and isoproturon (Legato Plus 600 SC), the highest reduction in the number of dicotyledonous weeds was observed; on average for the years by 29.2, 22 and 23.4 plants·m^{-2}, respectively, compared with the control, in which this number was 186 plants·m^{-2}. However, the other two combinations, i.e. MCPA together with sulfosulfuron (Chwastox Extra 300 SL and Apyros 75 WG), as well as fluoxypyr and florasulam with sulfosulfuron (Starane Super 101 SE and Apyros 75 WG), turned out to be less effective at reducing the number of dicotyledonous weeds, however, when compared with the control it was a significant reduction, on average by half (Fig. 1). In subsequent years of research, weed infestation was irregular on plantations of wheat cv. 'Monsun' sown at facultative time, from the mean 160.2 plants·m^{-2} in 2011 to 30.1 plants·m^{-2} in 2014. Only in one year, i.e. in 2013, a significant effect of glyphosate was observed on the reduction in the number of dicotyledonous weeds (by about 12 plants·m^{-2}) – data not presented here. However, on the background of average conditions in the three analyzed years (Fig. 1), such a difference was not statistically proven, we can only talk here about a tendency to maintain a lower number of weeds up to milk maturity in wheat after the application of glyphosate on a stubble field after forecrop cultivation. In many crop plants, it is recommended to use pre-sowing application of nonselective preparations containing glyphosate, allowing for an effective control of most weed species (Calado *et al*., 2010; Bajwa, 2014). This is a foliar herbicide controlling only weeds that emerged, thus its effect is short-term, and emergence of weeds in stands of winter cereals, as well as facultative ones, occurs throughout the whole winter and early spring period. However, even under these difficult conditions, pre-sowing application of glyphosate reduces weed infestation, but does not eliminate it completely (Adamczewski and Dobrzański, 2012). However, maintaining facultative cereal stands free of weeds usually requires supplementary application of weed control with foliar preparations or foliar-soil ones, ideally consisting of several active substances (Baghestani *et al.,* 2007a, b; 2008).

The reflection of the reduction in the number of weeds after application of studied active substances in herbicides and their mixtures was the reduction in the air dry mass (Fig. 2). On average over the three years of research, it was found that all preparations had an equally statistically proven effectiveness in this respect; compared with the control in relative values it was: 96% – Chisel 75 WG, 95% – Helmstar 75 WG, 93% – Legato Plus 600 SC, 78% – Chwastox Extra 300SL + Apyros 75 WG and 68 % Starane Super 101 SE + Apyros 75 WG. The air dry mass of dicotyledonous weeds was variable due to the application of glyphosate on stubble field after harvesting the forecrop. This long-term effect caused that weeds which developed after the application of glyphosate were smaller, weighed 86.9 g, while without glyphosate on average 118.3 g compared with all variants.

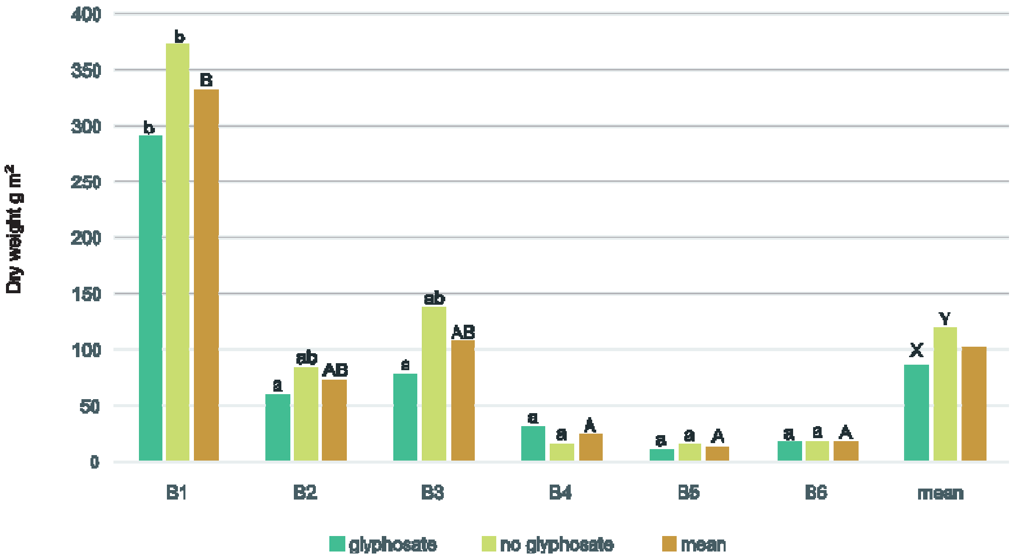
Analysis of the number and the air dry mass of monocotyledonous weeds

Compared with the number of monocotyledonous weeds, whose species in the spectrum was significantly less abundant than dicotyledonous one, a very strong effect of glyphosate was proven when it was used in the pre-sowing cultivation of facultative wheat cv. ‘Monsun’. This reduction in the number was on average three-fold over the years (Fig. 3). On plots where no herbicides were used, this difference was even more visible, as the number of monocotyledonous weeds was 146 plants·m^{-2}, while on the plot with glyphosate 26.8 plants·m^{-2}.



B1 – control, B2 – Chwastox Extra 300 SL (MCPA) 1.5 dm^3·ha^{-1} + Apyros 75 WG (sulfosulfuron) 15 g·ha^{-1} + Trend 90 EC (adjuvant), B3 – Starane Super 101 SE (fluoxypyr and florasulam) 1 dm^3·ha^{-1} + Apyros 75 WG (sulfosulfuron) 15 g·ha^{-1} + Trend 90 EC (adjuvant), B4 – Legato Plus 600 SC (diflufenican and isoproturon) 1.25 dm^3·ha^{-1}, B5 – Chisel 75 WG (thifensulfuron-methyl and chlorosulfuron) 40 g·ha^{-1} + Trend 90 EC (adjuvant), B6 – Helmstar 75 WG (tribenuron-methyl) 25 g·ha^{-1} + Trend 90 EC (adjuvant)
The same letters over bars in the series of data denote groups of not differing means based on Tuckey’s HSD test for $P < 0.05$

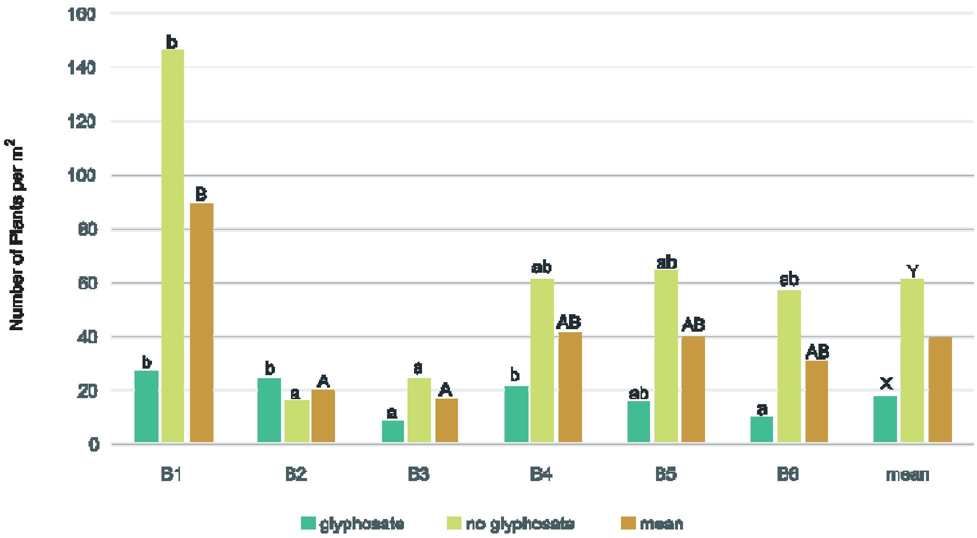
Fig. 1. Number of dicotyledonous weeds in spring wheat sown in late-autumn under the effect of using glyphosate and selective herbicides; means from the research years 2010–2014



B1 – control, B2 – Chwastox Extra 300 SL (MCPA) 1.5 dm^3·ha^{-1} + Apyros 75 WG (sulfosulfuron) 15 g·ha^{-1} + Trend 90 EC (adjuvant), B3 – Starane Super 101 SE (fluoxypyr and florasulam) 1 dm^3·ha^{-1} + Apyros 75 WG (sulfosulfuron) 15 g·ha^{-1} + Trend 90 EC (adjuvant), B4 – Legato Plus 600 SC (diflufenican and isoproturon) 1.25 dm^3·ha^{-1}, B5 – Chisel 75 WG (thifensulfuron-methyl and chlorosulfuron) 40 g·ha^{-1} + Trend 90 EC (adjuvant), B6 – Helmstar 75 WG (tribenuron-methyl) 25 g·ha^{-1} + Trend 90 EC (adjuvant)
The same letters over bars in the series of data denote groups of not differing means based on Tuckey's HSD test for $P < 0.05$

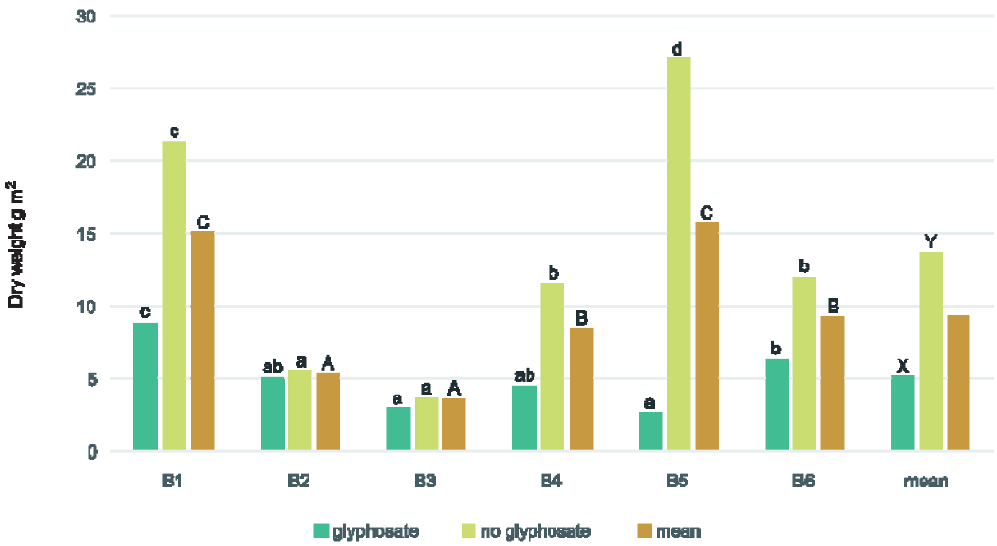
Fig. 2. The air dry mass of dicotyledonous weeds in spring wheat sown at the late-autumn date under the effect of using glyphosate and selective herbicides; means from the research years 2010–2014

The effect of herbicides applied in spring also had a statistically proven influence on the reduction of the number of monocotyledonous weeds, from 81 % in the case of Starane Super 101SE + Apyros 75 WG to 54% for herbicide Legato Plus 600 SC (Fig. 3). The effect of selective herbicides occurred in an interaction with glyphosate and without it. On plots with the application of glyphosate the number of monocotyledonous weeds was significantly reduced after the application of all active substances except MCPA and sulfosulfuron. On average for the studied period, glyphosate caused an almost 3-fold reduction in the development of the biomass of monocotyledonous weeds (Fig. 4). Among the studied active substances contained in selective herbicides, the highest effectiveness in this area was indicated in the case of herbicides Starane Super 101 SC + Apyros 75 WG, as well as Chwastox Extra 300SL + Apyros 75 WG, where the air dry mass was: 3.57 g and 5.35 g, respectively. In the case of herbicide Legato Plus 600 SC and Helmstar 75 WG this effect on the biomass of monocotyledonous weeds was weaker, as approximately 40% reduction was observed compared with the control. The most unreliable in this respect was application of the preparation Chisel 75 WG, after which the dry mass of monocotyledonous weeds was on the same level as in the control (Fig. 4). The number and mass of monocotyledonous weeds was significantly reduced when a pre-sowing herbicide (nonselective, systemic and unstable) glyphosate was introduced into wheat cultivation. Control of weeds before wheat cultivation significantly reduces potential threat during cultivation, as it minimizes disorders in the soil, which positively affects the occurrence of weeds (Marginet *et al*., 2000; Rahman *et al*., 2000). It may be indicated that under conditions of late-autumn sowing of spring wheat it is possible to reduce or even avoid application of post-emergence herbicides in wheat, as weeds may be effectively controlled before sowing. However, the decision to abandon supplementary weed control should be taken responsibly, based on the analysis of the current condition of weed infestation of wheat in spring (Soltani *et al*., 2006; Sonderskov *et al*., 2015).



B1 – control, B2 – Chwastox Extra 300 SL (MCPA) 1.5 dm^3·ha^{-1} + Apyros 75 WG (sulfosulfuron) 15 g·ha^{-1} + Trend 90 EC (adjuvant), B3 – Starane Super 101 SE (fluoxypyr and florasulam) 1 dm^3·ha^{-1} + Apyros 75 WG (sulfosulfuron) 15 g·ha^{-1} + Trend 90 EC (adjuvant), B4 – Legato Plus 600 SC (diflufenican and isoproturon) 1.25 dm^3·ha^{-1}, B5 – Chisel 75 WG (thifensulfuron-methyl and chlorosulfuron) 40 g·ha^{-1} + Trend 90 EC (adjuvant), B6 – Helmstar 75 WG (tribenuron-methyl) 25 g·ha^{-1} + Trend 90 EC (adjuvant)
The same letters over bars in the series of data denote groups of not differing means based on Tuckey's HSD test for $P < 0.05$

Fig. 3. Number of monocotyledonous weeds in spring wheat sown in late-autumn under the effect of using glyphosate and selective herbicides; means from the research years 2010–2014



B1 – control, B2 – Chwastox Extra 300 SL (MCPA) 1.5 dm^3·ha^{-1} + Apyros 75 WG (sulfosulfuron) 15 g·ha^{-1} + Trend 90 EC (adjuvant), B3 – Starane Super 101 SE (fluoxypyr and florasulam) 1 dm^3·ha^{-1} + Apyros 75 WG (sulfosulfuron) 15 g·ha^{-1} + Trend 90 EC (adjuvant), B4 – Legato Plus 600 SC (diflufenican and isoproturon) 1.25 dm^3·ha^{-1}, B5 – Chisel 75 WG (thifensulfuron-methyl and chlorosulfuron) 40 g·ha^{-1} + Trend 90 EC (adjuvant), B6 – Helmstar 75 WG (tribenuron-methyl) 25 g·ha^{-1} + Trend 90 EC (adjuvant)
The same letters over bars in the series of data denote groups of not differing means based on Tuckey's HSD test for $P < 0.05$

Fig. 4. The air dry mass of monocotyledonous weeds in spring wheat sown in late-autumn under the effect of using glyphosate and selective herbicides; means from the research years 2010-2014

CONCLUSION

Application of glyphosate in the post-harvest cultivation contributed to a three-fold reduction in the number of monocotyledonous weeds and in their biomass in the cultivation of facultative wheat cv. Monsun. Compared with dicotyledonous weeds, application of glyphosate had a significantly smaller effect. Among the studied selective herbicides, the highest effectiveness in reducing monocotyledonous weeds was indicated in the case of a mixture Starane Super 101 SC + Apyros 75 WG, as well as Chwastox Extra 300SL + Apyros 75 WG. The predominant weed in the cultivation of facultative wheat every year was *Viola arvensis*, which was most effectively reduced by herbicides containing tribenuron-methyl (Helmstar 75 WG), as well as thifensulfuron-methyl and chlorosulfuron (Chisel 75 WG). Tribenuron--methyl also turned out to be very effective in controlling *Chenopodium album*, *Matricaria inodora*, *Convolvulus arvensis* and *Capsella bursa-pastoris*. This chemical substance, however, was less effective in the control of *Plantago major*, *Taraxacum officinale* and *Fallopia convolvulus*. The highest reduction in the number of dicotyledonous weeds was observed after the application of the following chemical substances applied to foliage, i.e. tribenuron-methyl, thifensulfuron-methyl with chlorosulfuron, as well as diflufenican and isoproturon. Reduction in the biomass of dicotyledonous weeds for particular variants was as follows: 96% – Chisel 75 WG, 95% – Helmstar 75 WG, 93% – Legato Plus 600 SC, 78% – Chwastox Extra 300SL + Apyros 75 WG and 68% Starane Super 101 SE + Apyros 75 WG, respectively.

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WPŁYW WYBRANYCH SUBSTANCJI AKTYWNYCH HERBICYDÓW NA OGRANICZENIE ZACHWASZCZENIA W PSZENICY JAREJ WYSIANEJ W TERMINIE PÓŹNOJESIENNYM

Streszczenie

W doświadczeniu polowym prowadzonym w latach 2010-2014 sprawdzono wpływ jesiennego stosowania glifosatu oraz różnych substancji aktywnych w herbicydach selektywnych stosowanych na wiosnę na uszkodzenia roślin chwastów, liczebność i masę chwastów jednoliściennych i dwuliściennych w uprawie pszenicy jarej odmiany Monsun wysiewanej jako przewódka. Określono spektrum gatunkowe chwastów występujących w latach badań oraz skuteczność chwastobójczą glifosatu i wybranych herbicydów selektywnych. Największą redukcję liczebności chwastów dwuliściennych stwierdzono po wiosennym zastosowaniu tribenuronu metylowego, tifensulfuronu metylowego z chlorosulfuronem oraz diflufenicanu i isoproturonu. Redukcja biomasy chwastów dwuliściennych wyniosła dla poszczególnych wariantów odpowiednio: 96% - Chisel 75 WG, 95% - Helmstar 75 WG, 93% - Legato Plus 600 SC, 78% - Chwastox Extra 300SL + Apyros 75 WG i 68% Starane Super 101 SE + Apyros 75 WG. Zastosowanie glifosatu jesienią przed zasiewem przewódki przyczyniło się do trzykrotnego zmniejszenia liczby chwastów jednoliściennych oraz ich biomasy w uprawie pszenicy odmiany Monsun. Aby uzyskać najlepszy efekt ograniczania chwastów w uprawie pszenicy jarej w wysiewie późnojesiennym, po przedplonie zbożowym, należy zastosować glifosat w jesiennym zespole uprawy, a w wiosennym terminie odpowiednio do spektrum pojawiających się chwastów dobrać herbicyd, który zawiera co najmniej dwie substancje aktywne, np. tifensulfuron metylowy z chlorosulfuronem lub diflufenican z isoproturonem.

Słowa kluczowe: herbicyd nieselektywny, herbicyd selektywny, ograniczanie zachwaszczenia, pszenica przewódkowa, substancje aktywne herbicydów