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THE EFFECT OF REDUCED GROWTH RETARDANT RATES ON WEED INFESTATION OF A WINTER WHEAT (*TRITICUM AESTIVUM* L.) CROP

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ABSTRACT

In Poland, like in other countries of the world, cereals have a dominant position in the crop production structure, especially winter wheat. Cereals, in particular winter varieties, are prone to heavy weed infestation, both with dicotyledonous and monocotyledonous species. Therefore, weed management is one of important factors that affect yields of cereals and as a consequence the profitability of cereal growing.

The present study investigated the effect of full and reduced rates of three growth retardants with different active ingredients (chlormequat chloride (CC), trinexapac-ethyl (TE), and chlormequat chloride (CC) + ethephon (E)), used in combination with an adjuvant or without adjuvant, on the quantitative parameters of weed infestation and weed biodiversity in a winter wheat crop. Plots where no growth retardants were used were the control treatment.

The level of weed infestation of the winter wheat crop, as measured by the number and air-dry weight of weeds, was significantly differentiated by weather conditions, year and growth regulator rates. The study results show that growth retardant rates can be reduced in winter wheat growing without the risk of increased weed infestation. Chlormequat chloride + ethephon and trinexapac-ethyl showed the highest effectiveness in reducing weed infestation. The study found a positive trend towards reducing the number and weight of weeds under the influence of the adjuvant used (oil SN 76%). But this agent only slightly affected the species composition and constancy of the weed community. The dominant species in the winter wheat crop were *Chenopodium album*, *Veronica persica* and *Viola arvensis*, which were placed in constancy class IV. The lower the retardant rate applied, the more their numbers decreased, whereas the number of other weed species were generally reduced by standard rates of weed control agents.

Key words: *Triticum aestivum*, growth retardant, adjuvant, weed infestation.

INTRODUCTION

The yielding ability of crop plants is significantly affected by the level of protection of a plantation against the invasion of agricultural pests, in particular the reduction of weed competition (Miller et al. 2013). Cereal plants compete with weeds for light, water, nutrients, and space necessary for life (Borówczak et al., 2008; Ashrafi et al., 2009). A result of the harmful effects of weeds is the growth inhibition of the crop plant and as a consequence a reduction in yield and deterioration of its quality (Young et al., 1994; Cousens and Mortimer, 1995; Oerke, 2006). Weeds often cause hindrances during harvest and increase grain contamination and moisture content. Research results show that cereal varieties exhibit varying capacity to compete with weed infestation in the crop due to their different morphological characters (Seavers and Wright, 1999; Christensen, 2006). The competitive ability of cereal varieties against weeds is determined to the greatest extent by traits such as plant height, initial growth rate, leaf area, leaf angle, and canopy architecture (Lemerle et al., 1996; Eisele and Köpke, 1997). In agricultural practice, chemical weed control with full or reduced rates of pesticides is usually necessary. Properly selected mechanical and chemical methods are used to manage weeds and they are primarily designed to eliminate the most troublesome weed species (Woźnica et al., 2000). These methods involve the use of different crop protection agents, including growth retardants. The action of growth retardants consists in the inhibition of elongation growth of cereal stems, thereby contributing to the formation of lower cereal crops and modifying weed communities colonizing them (Rajala and

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Peltonen-Sainio, 2001). Adjuvants are used more and more frequently to support the action of these agents. These are aiding substances that increase the biological activity of agents to which they are added (Gaskin et al., 2000; Dobrzański and Adamczewski, 2002). A doubtless benefit of using adjuvants is the possibility to reduce rates of growth regulators without compromising their effectiveness, which lowers crop protection costs and is an environment-friendly measure (Skrzypczak et al., 2003).

The aim of the present study was to compare the effect of three growth retardants applied at full and reduced rates on the quantitative parameters of weed infestation as well as on the species composition and constancy of weeds in a winter wheat crop.

MATERIAL AND METHODS

Experimental design

A field study was carried out at the Czesławice Experimental Farm ($51^0 30'$N; $22^0 26'$E), belonging to the University of Life Sciences in Lublin, in the period 2004-2007. It was located on grey-brown podzolic soil (sandy), designated as PWsp, slightly acidic (pH in 1M KCl – 6.3-6.6) and rich in phosphorus, potassium, and magnesium. The experiment was set up as a split-split-plot design in 3 replicates, in 10 m^2 plots. The experimental design included treatments without growth retardant (WR) and with the following growth retardants: Antywylegacz Płynny 675 SL (chlormequat chloride, CC – (675 $g \cdot l^{-1}$), Moddus 250 EC (trinexapac-ethyl, TE – 250 $g \cdot l^{-1}$), and Cecefon 465 SL (chlormequat chloride, CC – 310 $g \cdot l^{-1}$ + ethephon, E – 155 $g \cdot l^{-1}$), applied at recommended rates and at rates reduced by 50 or 67%. The growth retardants were applied as follows: CC at the 1st node stage of wheat (BBCH 31); TE and CC + E at the 2^{nd} node stage of wheat (BBCH 32) – together with the adjuvant Atpolan 80 EC (76% of SN 200 mineral oil) or without adjuvant. They were applied with a P161 field sprayer (Tee-Jet Turbo 02) at a pressure of 0.25 MPa, using 250 l of liquid per hectare. Winter wheat, cv. 'Muza', followed vetch grown for seed. Tillage for wheat was done using good agricultural practices. Mineral fertilization in kg of nutrient per hectare was as follows: 100 kg $N \cdot ha^{-1}$, 40 kg $P \cdot ha^{-1}$, 110 kg $K \cdot ha^{-1}$. The whole experiment was sprayed with the herbicides Apyros 75 WG (sulphonylurea, at a rate of $20 g \cdot ha^{-1}$) and Starane 250 EC (fluroxypyr 250 $g \cdot l^{-1}$, at a rate of 0.6 $l \cdot ha^{-1}$) at full tillering stage (BBCH 29-30). Alert 375 SC (a.i. flusilazole 125 $g \cdot l^{-1}$ + carbendazim 250 $g \cdot l^{-1}$) at a rate of 1 $l \cdot ha^{-1}$ and Tilt Plus 400 EC (a.i. propiconazole 125 $g \cdot l^{-1}$ + fenpropidin 275 $g \cdot l^{-1}$) at a rate of 1 $l \cdot ha^{-1}$ were used against fungal diseases. The wheat tested was sown in the third 10-day period of September at a seeding density of 500 germinating seeds per 1 m^2. Before sowing, seeds were treated with Dividend 030 FS (a.i. difenoconazole 30 $g \cdot l^{-1}$) at a rate of 300 ml of the seed dressing per 100 kg of seeds. The wheat crop was harvested at the end of July. Weed infestation of the winter wheat crop was determined based on the numbers, air-dry weight and species composition of weeds per $1 m^2$ during the study years. Weed infestation was evaluated by the dry-weight-rank method at the beginning of the heading stage of winter wheat (BBCH 51). For this purpose, a 0.5 m^2 frame was used which was placed randomly in each plot twice. Names of weed species followed Mirek et al. (2002). The crop height of winter wheat plants was determined before harvest (measuring it from the soil surface to the ear tip, excluding awns).

Statistical analysis

The study results were statistically analysed by analysis of variance, while the differences between means were evaluated by Tukey's test at a significance level of $\alpha = 0.05$. The statistical analysis was presented using Statgraphics 5.0 software. Constancy classes, which followed Braun-Blanquet (1964), were determined based on a 3-year analysis of weed infestation of the winter wheat crop.

Weather conditions at the study site

Weather conditions varied between years (Table 1). The differences related mainly to the amount and distribution of rainfall during the growing season of winter wheat. The

2004/2005 season was characterized by above-average rainfall (by 29.7 mm) and air temperature higher than the long-term mean by 0.6°C. In May 2005 the rainfall exceeded the long-term mean by 89.2 mm. On the other hand, in the 2005/2006 season there was a rainfall deficit, while the temperature was close to the long-term average. The spring and summer months (except for March and May) proved to be drier than average. The 2006/2007 growing season was average in terms of precipitation, but it was much warmer compared to the previous study seasons. The average temperature during growth was higher by 2.5°C compared to the long-term mean.

Table 1. Temperature (^0C) and rainfall (mm) during the vegetation seasons of winter wheat

Months	Years						Mean of years (1951-2005)	
	2004/2005		2005/2006		2006/2007			
	mm	^{0}C	mm	^{0}C	mm	^{0}C	mm	^{0}C
IX	21.1	12.5	23.1	14.7	10.1	15.1	51.6	12.6
X	26.1	9.8	4.2	8.7	31.0	9.8	40.1	7.8
XI	65.5	2.8	24.6	2.7	43.7	4.7	38.1	2.5
XII	15.8	1.1	55.7	-1.3	22.7	2.5	31.5	-1.4
I	34.8	-0.7	16.1	-8.2	83.7	2.0	22.7	-3.5
II	35.4	-4.0	24.4	-4.6	23.8	-2.0	25.6	-2.7
III	42.2	-1.1	47.4	-2.0	32.6	5.7	26.3	1.1
IV	21.2	8.4	26.1	8.5	16.4	8.2	40.2	7.4
V	146.9	13.0	68.1	13.3	46.4	14.9	57.7	13.0
VI	48.0	15.6	23.2	16.9	85.1	18.2	65.7	16.2
VII	55.8	19.8	26.6	21.1	70.0	18.8	83.5	17.8
VIII	46.2	17.0	202.5	17.4	31.4	18.8	68.6	17.1
Total/ Average	559.0	7.8	542.0	5.8	496.9	9.7	551.7	7.3

RESULTS

Number and weight of weeds

The number of weeds in the winter wheat crop was significantly differentiated by weather conditions during the study period (Table 2).

In the first year of the experiment (2005), there were 153.0 weeds per 1 m^2, i.e. 94 and 75% more than in the next study seasons. The situation with weed biomass produced was similar; it was the highest in 2005 – 62.09 g·m^{-2}, whereas the lowest in the second year of the study – 3.63 g·m^{-2} (Table 3).

The growth regulators used also had a clear effect on weed infestation in the winter wheat crop, sine the differences in the numbers of weeds in the compared treatments with growth retardants reached up to 31%, while relative to the control treatment 44%. The significantly lowest number of weeds was found in the treatments sprayed with TE at a rate reduced by 67% (0.13 l·ha^{-1}) and CC + E at a rate reduced by 33% (1 l·ha^{-1}) – 54 plants·m^{-2}, whereas the highest number was found in the plots sprayed with CC + E at the recommended rate (2.0 l·ha^{-1}) – 77.8 plants ·m^{-2}. The number of weeds in the control treatment was 96.3 plants·m^{-2}. All growth regulator rates applied (except for the recommended rate of CC + E) significantly reduced the numbers of weeds compared to that found in the control treatment. Weeds growing in the control treatment (without retardant) produced a biomass of 28.26 g·m^{-2}. The growth regulators used at standard rates and at rates reduced by 33% contributed to a slight increase in the trait in question. An opposite situation, thus a decrease in weed biomass, was recorded in the plots with the most reduced rates (by 67%).

The tested adjuvant Atpolan 80 EC did not change significantly weed infestation of the winter wheat crop. Nevertheless, it should be noted that its addition to CC, regardless of the rate applied, had a beneficial effect on reducing the weight and number of weeds in the crop (Tables 2 and 3). In the case of TE, an opposite effect was obtained with the standard rate and with the rate reduced by 33% – an increase in the number and air-dry weight of weeds, whereas in the case of CC + E this adjuvant produced divergent results.

Table 2. Number of weeds per $1m^2$ in the winter wheat crop

Treatment	Rate $l \cdot ha^{-1}$	Mean for adjuvant		Years			Mean
		a	b	2005	2006	2007	
WR		96.3		223.0	6.0	60.0	96.3
CC	2.0	75.0	59.0	134.0	4.5	62.5	67.0
	1.0	73.0	64.0	166.5	6.5	32.5	68.5
	0.16	60.0	58.0	138.0	19.5	19.5	59.0
TE	0.4	53.6	74.3	136.5	5.0	50.5	64.0
	0.2	64.3	75.0	165.5	10.0	33.5	69.6
	0.13	65.0	43.0	128.0	15.0	18.0	54.0
CC + E	2.0	84.6	71.0	173.5	6.0	54.0	77.8
	1.0	57.0	52.0	125.0	8.0	29.0	54.0
	0.16	42.0	72.0	140.0	14.0	16.0	57.0
Mean		67.1	66.4	153.0	9.4	37.6	66.7
LSD $_{(p=0.05)}$ between: years – 9.23; adjuvants – n.s.; treatments – 22.7; years x treatments – 44.2							

a – without adjuvant; b – adjuvant Atpolan 80 EC; n.s. – not significant.

Table 3. Air-dry weight of weed in the winter wheat crop ($g \cdot m^{-2}$)

Treatment	Rate $l \cdot ha^{-1}$	Mean for adjuvant		Years			Mean
		a	b	2005	2006	2007	
WR		28.26		34.96	2.26	47.58	28.26
CC	2.0	38.32	59.0	30.35	69.14	32.15	34.34
	1.0	40.75	64.0	26.64	70.64	29.03	33.70
	0.16	24.04	58.0	23.76	51.00	11.69	23.90
TE	0.4	36.04	74.3	42.76	75.10	42.7	39.40
	0.2	35.99	75.0	37.26	73.78	30.28	36.62
	0.13	27.84	43.0	17.28	54.82	7.47	22.56
CC + E	2.0	46.11	71.0	37.25	83.80	39.97	41.68
	1.0	27.95	52.0	31.62	58.60	27.22	29.78
	0.16	19.07	72.0	24.59	49.06	10.97	21.83
Mean		32.35	30.06	62.09	3.63	27.91	31.21
LSD $_{(p=0.05)}$ between: years – 4.797; adjuvants – n.s., treatments – 11.828; years x treatments – 22.961							

a – without adjuvant; b – adjuvant Atpolan 80 EC; n.s. – not significant.

Plant height

The above-mentioned growth regulators, in combination with the adjuvant Atpolan 80 EC, had a clear beneficial effect on the crop height of winter wheat stems, changing it on average by 3 cm (Table 4).

Table 4. Winter wheat plant height (cm)

Treatment	Rate $l \cdot ha^{-1}$	Mean for adjuvant		Years			Mean
		a	b	2005	2006	2007	
WR		92.3		99.8	92.9	84.3	92.3
CC	2.0	79.6	74.0	80.7	80.7	69.0	76.8
	1.0	81.4	80.3	81.9	82.2	78.4	80.8
	0.16	84.1	80.6	82.9	82.3	81.9	82.4
TE	0.4	80.4	72.1	78.8	83.0	66.8	76.2
	0.2	84.8	83.1	86.6	86.8	78.6	84.0
	0.13	87.6	87.2	94.2	87.2	80.9	87.4
CC + E	2.0	75.2	71.1	76.8	73.2	69.6	73.2
	1.0	81.7	78.9	82.2	80.6	78.2	80.3
	0.16	83.8	81.4	86.4	81.8	79.8	82.6
Mean		83.1	80.1	85.0	83.0	76.8	81.6
LSD $_{(p=0.05)}$ between: years – 4.797; adjuvants – n.s., treatments – 11.828; years x treatments – 22.961							

a – without adjuvant; b – adjuvant Atpolan 80 EC.

Over the 3-year study period, the longest wheat stems (92.3 cm) were recorded in the control treatment (without retardant). All the growth retardants used and their rates significantly shortened the height of the crop plant in question, and this effect was the greatest in the case of CC + E at the recommended rate – 2 $l \cdot ha^{-1}$ (stems were shortened by 20.7%). This fact was translated into significantly the highest air-dry weight of weeds and a distinctly higher number of weeds under the conditions of application of Cecefon 465 SL compared to the other treatments. The lowest retarding effect, though significant, was found in the case where TE was used at a rate reduced by 67% (87.4 cm).

The study found a significant effect of weather conditions on winter wheat plant height. The differences in the wheat crop height between years were 9.6%. In the last year of the study, stems were found to be shorter by 8.2 cm compared to their height in the first year. A beneficial reduction (by 3.6%) in winter wheat stem length was obtained under the influence of the adjuvant Atpolan 80 EC.

The floristic composition

As regards the floristic composition of the winter wheat crop, similar number of weed species was recorded in the treatments with growth retardants without adjuvant (Table 5) and combined with adjuvant (Table 6). The applied rates of growth regulators slightly affected the species biodiversity of the phytocoenoses studied. Most weed taxa reached numbers lower than 1 $plant \cdot m^{-2}$ in the crop. Due to this, the efficacy of the herbicides used should be considered to be satisfactory and it should be presumed that the occurrence of these taxa did not have a major effect on the yielding ability of the crop plant under study. The following annual weeds: *Veronica persica, Apera spica-venti, Viola arvensis,* and *Veronica arvensis*, largely dominated in the control treatment (without retardant) and in the case of growth retardant application. This means that the herbicides Apyros 75 WG and Starane 250 EC, applied at full tillering stage of winter wheat, were the least effective against these species. Additionally, the following species:

Echinochloa crus-galli, Capsella bursa-pastoris, and *Chenopodium album*, reached significant numbers, i.e. more than 1 plant·m^{-2}, in the control treatments and also generally in the plots with retardants. The above-mentioned taxa as well as *Elymus repens* and *Stellaria media*, which occurred in some of the plots, were found to be the dominant taxa under the conditions of the present experiment.

Table 5. Numbers of weed species per 1 m^2 in the winter wheat crop depending on the rate of growth retardants used without adjuvant (mean for 3 years)

Species	Treatment									
	WR	CC			TE			CC + E		
		Rate in l·ha^{-1}								
		2.0	1.0	0.67	0.4	0.2	0.13	2.0	1.0	0.67
Veronica persica POIR.	18.9	21.6	10.8	4.0	20.0	12.7	4.8	19.1	10.4	3.8
Apera spica-venti (L.) P. BEAUV.	53.4	23.7	35.1	24.6	13.3	29.5	23.7	43.6	24.1	11.7
Viola arvensis MURRAY	9.9	15.4	11.6	6.5	10.4	9.6	9.8	12.4	10.8	8.3
Veronica arvensis L.	3.0	0.0	3.6	5.3	3.6	3.6	4.8	2.3	2.9	2.9
Echinochloa crus-galli (L.) BEAUV.	2.1	0.0	0.0	-	0.0	0.0	-	0.0	0.0	-
Capsella bursa-pastoris (L.) MEDIK.	1.9	5.0	3.3	0.0	2.4	1.2	0.0	2.2	1.0	0.0
Chenopodium album L.	1.8	2.0	1.7	1.1	1.0	1.2	3.3	1.6	1.7	3.7
Stellaria media (L.) VILL	0.0	2.2	0.0	3.6	0.0	0.0	3.4	0.0	0.0	1.1
Elymus repens (L.) GOULD	0.0	1.2	4.0	6.9	0.0	2.1	2.0	0.0	2.8	3.8
Fallopia convolvulus (L.) Á. LÖVE	0.0^x	-	-	0.0	-	-	0.0	-	-	2.0
Lamium amplexicaule L.	0.0	-	-	1.8	-	-	0.0	-	-	0.0
Equisetum arvense L.	0.0	0.0	-	0.0	-	1.1	1.7	0.0	0.0	0.0
Sonchus arvensis L.	-	-	-	1.8	-	-	1.2	-	-	0.0
Poa annua L.	-	-	-	0.0	-	0.0	2.4	-	0.0	1.7
Other species	5.3	3.9	2.9	4.4	2.9	3.3	7.9	3.4	3.3	3.0
Number of weeds	96.3	75.0	73.0	60.0	53.6	64.3	65.0	84.6	57.0	42.0
Number of weed species	16	21	15	23	16	19	24	18	18	23

0.0x – the species found in a number less than 0.1 plant.m-^{2}; - – the species did not occur.

Table 6. Numbers of weed species per 1 m^2 in the winter wheat crop depending on the rate of growth retardants used with adjuvant (mean for 3 years)

Species	Treatment									
	WR	CC			TE			CC + E		
		Rate in l·ha^{-1}								
		2.0	1.0	0.67	0.4	0.2	0.13	2.0	1.0	0.67
Veronica persica POIR.	18.9	17.1	7.2	2.2	14.4	5.1	2.9	18.9	3.8	1.2
Apera spica-venti (L.) P. BEAUV.	15.7	12.5	33.2	30.2	31.0	36.7	20.3	25.2	24.3	49.1
Viola arvensis MURRAY	9.9	12.2	12.0	7.8	13.9	14.0	7.3	14.7	12.1	6.0
Veronica arvensis L.	3.0	6.1	4.3	2.4	7.7	4.6	0.0	4.9	4.1	2.9
Echinochloa crus-galli (L.) BEAUV.	2.1	0.0	-	-	0.0	-	-	0.0	-	0.0
Capsella bursa-pastoris (L.) MEDIK.	1.9	0.0	0.0	0.0	2.0	0.0	-	2.1	1.0	0.0
Chenopodium album L.	1.8	1.1	1.2	2.5	2.0	2.6	2.7	1.5	1.2	2.8
Stellaria media (L.) VILL	0.0	0.0	1.1	1.9	-	1.7	0.0	0.0	1.4	2.3
Elymus repens (L.) GOULD	0.0	0.0	0.0	1.4	0.0	1.2	0.0	0.0	0.0	0.0
Fallopia convolvulus (L.) Á. LÖVE	0.0^x	-	-	0.0	-	-	-	0.0	-	0.0
Lamium amplexicaule L.	0.0	1.2	2.7	2.6	0.0	2.1	3.2	1.5	1.6	3.0
Equisetum arvense L.	0.0	0.0	0.0	0.0	0.0	1.6	1.6	0.0	0.0	0.0
Sonchus arvensis L.	-	-	0.0	1.1	-	1.9	0.0	-	1.1	0.0
Poa annua L.	5.3	8.8	2.3	5.9	3.3	3.5	5.0	2.2	1.4	4.7
Other species	96.3	59.0	64.0	58.0	74.3	75.0	43.0	71.0	52.0	72.0
Number of weeds	16	16	16	21	15	18	17	15	19	21
Number of weed species	18.9	17.1	7.2	2.2	14.4	5.1	2.9	18.9	3.8	1.2

0.0^x – the species found in a number less than 0.1 plant.m-^{2}; - – the species did not occur.

The constancy index

On the basis of the constancy classes of weeds in the winter wheat crop, it can be concluded that the effect of growth retardants used on the components of this agricultural ecosystem was similar in the treatments without adjuvant (Table 6) and in the treatments where it was used (Table 7). 3 species: *Chenopodium album*, *Veronica persica*, and *Viola arvensis*, infested the wheat crop most strongly (class IV) (Tables 7 and 8). *Apera spica-venti*, *Veronica persica, Chenopodium album*, and *Capsella bursa-pastoris* were equally troublesome in the control treatment (Table 7 and 8). Taxa recorded in constancy class III were a frequent component of weed infestation. Species recorded in at least 40% of observations were included in this class. In the plots with retardants but without adjuvant, these were: *Veronica persica, Viola arvensis, Chenopodium album, Capsella bursa-pastoris, Galium aparine, Apera spica-venti, Matricaria maritima* subsp. *inodora,* and *Elymus repens.* In the treatments with both retardants and adjuvant, this was additionally *Echinochloa crus-galli.*

Species loosely associated with the agrocenosis in question, recorded in constancy class I or II were the least troublesome weeds. They infested not more than 20% of the plots investigated.

The application of the adjuvant aiding the action of the growth regulators did not have a significant effect on changes in the numbers and frequency of occurrence of weed species colonising the winter wheat crop. Only a slight decline in the numbers of taxa found in the lowest constancy classes (I and II) and a slight increase in the numbers of constant and frequent species (IV and III) were recorded under its influence.

Table 7. Constancy of weeds in the winter wheat crop in the plots without adjuvant (mean for 3 years)

Species		Treatment									
		WR	CC			TE			CC + E		
			Rate in l·ha^{-1}								
			2.0	1.0	0.67	0.4	0.2	0.13	2.0	1.0	0.67
1.	*Apera spica-venti* (L.) P. BEAUV.		II	II	II	II	II	III	II	III	II
2.	*Veronica persica* POIR	III	III	IV	II	IV	III	III	IV	III	III
3.	*Viola arvensis* MURRAY	III	III	III	III	III	III	III	III	III	III
4.	*Capsella bursa-pastoris* (L.) MEDIK.	II	III	III	II	II	II	II	II	II	I
5.	*Veronica arvensis* L.	II	II	II	II	II	II	II	II	II	III
6.	*Chenopodium album* L.	II	IV	III	III	II	III	III	III	II	II
7.	*Elymus repens* (L.) GOULD	II	II	III	II	II	III	II	III	II	II
8.	*Stellaria media* (L.) VILL	I	II	II	II	II	II	II	II	II	II
9.	*Galium aparine* L.	I	II	III	II	I	II	I	II	I	I
10.	*Echinochloa crus-galli* (L.) BEAUV.	I	II	I	-	I	I	-	-	II	-
11.	*Matricaria maritima* subsp. *indora* L.	I	II	II	I	II	III	II	II	II	II
12.	*Poa annua* L.	I	I	-	II	-	I	II	II	II	II
13.	*Equisetum arvense* L.	I	II	-	II	-	I	II	II	II	II
14.	*Sonchus arvensis* L	I	I	-	I	-	I	I	-	-	II
15.	*Geranium pusillum* BURM. F. EXL.	-	II	-	II	II	I	-	I	I	II
16.	*Fallopia convolvulus* (L.) Á. LÖVE	-	I	-	-	-	I	-	I	-	-
Number of weed species in constancy classes C:	IV	1	1	1	-	1	-	-	1	-	-
	III	2	3	4	2	1	5	4	3	3	3
	II	4	9	4	10	8	5	6	8	9	9
	I	7	3	1	2	2	6	2	2	1	2

– The species did not occur.

Table 8. Constancy of weeds in the winter wheat crop in the plots with adjuvant
(mean for 3 years)

Species		WR	CC			TE			CC + E		
			Rate in l·ha^{-1}								
			2.0	1.0	0.67	0.4	0.2	0.13	2.0	1.0	0.67
1.	*Apera spica-venti* (L.) P. BEAUV.	IV	II	III	III	II	III	II	II	III	II
2.	*Veronica persica* POIR	III	III	III	III	IV	III	IV	IV	III	III
3.	*Viola arvensis* MURRAY	III	III	III	III	IV	III	II	III	III	II
4.	*Capsella bursa-pastoris* (L.) MEDIK.	II	II	II	III	II	II	-	II	II	I
5.	*Veronica arvensis* L.	II	II	III	II	II	II	II	II	II	II
6.	*Chenopodium album* L.	II	III	III	IV	II	III	III	III	III	III
7.	*Elymus repens* (L.) GOULD	II	II	IV	II	II	III	III	III	III	II
8.	*Stellaria media* (L.) VILL	I	I	II	II	-	II	II	II	III	II
9.	*Galium aparine* L.	I	I	-	II	II	II	I	I	I	II
10.	*Echinochloa crus-galli* (L.) BEAUV.	I	III	-	-	II	-	-	II	-	I
11.	*Matricaria maritima* subsp. *indora* L.	I	I	I	II	III	II	II	II	II	II
12.	*Poa annua* L.	I	I	II	II	-	II	II	-	II	II
13.	*Equisetum arvense* L.	I	I	I	II	I	II	II	-	-	II
14.	*Sonchus arvensis* L	I	-	I	-	I	II	-	-	-	-
15.	*Geranium pusillum* BURM. F. EXL.	-	-	-	I	-	-	-	-	-	-
16.	*Fallopia convolvulus* (L.) Á. LÖVE	IV	II	III	III	II	III	II	II	III	II
Number of weed species in constancy classes C:	IV	1	-	1	1	2	-	1	1	-	-
	III	2	4	5	4	1	5	2	3	5	2
	II	4	4	3	7	6	8	7	6	5	9
	I	7	5	3	1	2	-	1	1	5	2

– The species did not occur.

DISCUSSION

Cereals require properly selected mechanical and chemical weed control methods due to their varying competitive ability against weeds (Dastgheib et al., 1999; Piekarczyk, 2005; Romero et al., 2008). These methods include the use of different crop protection agents, including growth retardants, in order to obtain satisfactory yields and to eliminate unnecessary weed infestation. In the present study, weed infestation, as measured by the number and air-dry weight of weeds, was differentiated to the largest extent by years (in more than 90%) and growth regulators used (in more than 30%). The significantly highest number of weeds was recorded in the winter wheat crop in the year 2005 which was characterized by above-average total rainfall and mean air temperature. In the other drier years, the amount of rainfall was more than three – four times lower. The effect of weather conditions during the growing season on the number and air-dry weight of weeds in a winter wheat crop has been proved by Wanic et al. (2010) and Santín-Montaná et al. (2013). In the research of Derksen et al. (1995), the number and weight of weeds depended on tillage methods, while Douced et al. (1999), Buraczyńska and Ceglarek (2008) showed a significant influence of the previous crop on the above-mentioned weed infestation parameters.

The task of growth retardants is to increase the resistance of cereals to lodging by reducing the length of their particular internodes and to protect yield produced (Cox and Otis, 1989). Ecological and economic reasons induce farmers and researchers to use reduced rates of crop protection agents. The present study showed a positive effect of retardant treatments both on winter wheat plant height and on reduced weed infestation in the crop. The last year of the study proved to be the most beneficial for the action of the retardants, since in that year plants were found to be lower by 8.2 cm compared plant height found in the first year. All the anti-lodging agents used reduced the height of wheat plants, but TE and CC + E (applied at standard rates) to the greatest degree. The above-mentioned growth regulators applied at the most reduced rate (by 67%) were characterized by a high effect in decreasing the numbers and weight of weeds. The higher increase in biomass than in the number of weeds proves that a less dense crop was conducive not only to weed emergence, but it also promoted their luxuriant growth (Korres and Froud-Williams, 2002; Asif et al., 2013). Skrzyczyńska and Pawlonka (2004) also found a reduction in weed infestation of a winter triticale crop as influenced by growth retardants at a lower level of N (50 kg·ha^{-1}).

In addition to natural and anthropogenic factors, the floristic composition of a weed community in a cereal crop is affected by the type and intensity of crop protection treatments (Warcholińska, 1994). In the research of Pinke et al. (2009), the variation in the weed species composition was dependent on the type of field, crop protection, and climatic variation, including altitude. In the present study, the species richness of weeds was similar both in the treatments with adjuvant and without adjuvant application. The dominant taxa in both experimental treatments were as follows: *Veronica persica, Apera spica-venti, Viola arvensis, Veronica arvensis, Echinochloa crus-galli*, and *Chenopodium album.* Moreover, the following reached significant numbers: *Capsella bursa-pastoris, Stellaria media, Elymus repens*, and *Sonchus arvensis* in the treatment with CC*;* *Capsella bursa-pastoris, Stellaria media, Poa annua, Elymus repens*, and *Equisetum arvense* in the treatment with TE*;* *Capsella bursa-pastoris, Fallopia convolvulus*, and *Elymus repens* in the plot treated with CC + E.

The addition of the adjuvant Atpolan 80 EC to the spray solution of the growth regulators resulted in similar constancy of all weed species. This means that this adjuvant modified only slightly the investigated weed community colonising the winter wheat crop. On the other hand, the study found a positive, though statistically not significant, effect of the adjuvant on the reduction of weed infestation as measured by the number and air-dry weight of weeds in the crop. The best effects in reducing weed infestation were found after the application of CC, these effects were slightly lower for CC + E, while TE was shown to have the lowest effectiveness.

CONCLUSIONS

Weather conditions during the study period only slightly affected the species richness of weeds in the winter wheat crop, but they strongly differentiated their numbers and dry weight. All growth retardants used, irrespective of the rate applied, effectively reduced the number of weeds per unit area, whereas the reduced rates of these growth regulators decreased the most air-dry weight of weeds (by 67%). CC + E and TE showed the highest effectiveness in reducing weed infestation. Winter wheat plant height was dependent on the growth retardant rate, year and to a slight degree on the adjuvant applied. The study found a positive trend towards reducing the number and weight of weeds under the influence of the adjuvant Atpolan 80 EC. But this agent had only a slight effect on the species composition and constancy of the weed community. *Chenopodium album*, *Veronica persica* and *Viola arvensis*, placed in class IV constancy, were predominant in weed infestation of the winter wheat crop. The lower the retardant rate applied, the more their numbers decreased, whereas the number of other weed species was generally reduced by standard rates of weed control agents.

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