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WEED INFESTATION OF WINTER WHEAT (*Triticum aestivum* L.) UNDER THE CONDITIONS OF APPLICATION OF SOME RETARDANTS

Elżbieta Harasim, Marian Wesołowski

Department of Herbology and Plant Cultivation Techniques, University of Life Sciences in Lublin
20-950 Lublin, Akademicka 13, Poland
e-mail: elzbieta.harasim@up.lublin.pl

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Abstract

A field study was conducted in the period 2004–2007 on grey-brown podzolic soil (sandy). This study analysed the relationship between the use of stem shortening in cereals by means of retardants with the following active substances: chlormequat chloride (Antywylegacz Płynny 675 SL), trinexapac-ethyl (Moddus 250 EC), chlormequat chloride + ethephon (Cecefon 465 SL), and weed infestation. The retardants were applied at the 1st node stage (BBCH 31 – Antywylegacz Płynny 675 SL) and the 2nd node stage of winter wheat (BBCH 32 – Moddus 250 EC and Cecefon 465 SL), together with the adjuvant Atpolan 80 EC (75% of SN 200 mineral oil) or without the adjuvant. Winter wheat, cv. 'Muza', was grown after vetch grown for seed. The whole experiment was sprayed with the herbicides Apyros 75 WG and Starane 250 EC at the full tillering stage (BBCH 29–30). Plots where no growth regulators were used were the control treatment.

Weed density and biomass showed great variation between years. In the winter wheat crop, *Veronica persica, Viola arvensis, Veronica arvensis, Capsella bursa-pastoris*, and *Chenopodium album* dominated in the dicotyledonous class, whereas *Apera spica-venti*, *Echinochloa crus-galli*, and *Elymus repens* were predominant among monocotyledonous plants. 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 years and retardants used as well as by interactions of these factors. The adjuvant Atpolan 80 EC did not have a significant effect on the above-mentioned weed infestation parameters.

Key words: *Triticum aestivum*, crop, application, retardant, weed community, number of weed, reduction

INTRODUCTION

Growth regulators (retardants) are commonly used in cereal cropping. They reduce lodging of cereals and protect grain yield produced. The action of retardants consists in inhibiting stem elongation growth in cereals, due to which they form lower crop canopies and modify weed communities inhabiting such cereal crops (Rajala and Peltonen-Sainio, 2001; Kierzek and Głowacki, 2004). In order to reinforce the action of these agents, adjuvants are used more and more frequently in agricultural practice. These are additives that enhance the biological activity of agents to which they are added (Gaskin et al. 2000). Among cereals, winter wheat is particularly exposed to weed expansion due to its slow growth in the autumn and spring until the stem elongation stage (Skrzyczyńska and Pawlonka, 1999; Anjum and Bajwa, 2010). Winter wheat is also characterized by low competitive ability against weeds for nutrients, water, place in the canopy, and access to light. In the opinion of Skrzyczyńska and Pawlonka (2004), by shortening stems of cereal plants, retardants promote deeper penetration of light into the crop canopy and thus create more favourable conditions for emergence of weeds as well as their growth and development. In growing wheat, herbicides and growth regulators are used in agricultural practice, but the available literature lacks sufficient and well documented information how retardants, used in combination with adjuvants, affect a weed community.

The aim of the present study was to verify the thesis about the modifying effect of retardant application in a winter wheat crop on weed infestation of such a crop.

MATERIALS AND METHODS

A field study was carried out at the Czesławice Experimental Farm, 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 in a randomized block design in three replicates, in 10 m^2 plots. The experimental design included treatments without retardant (control treatment) and with retardants: chlormequat chloride (Antywylegacz Płynny 675 SL, 675 g × l^{-1}), trinexapac-ethyl (Moddus 250 EC, 250 g × l^{-1}), and chlormequat chloride + ethephon (Cecefon 465 SL, 310 g × l^{-1} + 155 g × l^{-1}). The retardants were applied at a rate recommended for the 1st node stage (BBCH 31) – chlormequat chloride, and the 2nd node stage of wheat (BBCH 32) – trinexapac-ethyl and chlormequat chloride + ethephon, with the adjuvant Atpolan 80 EC (75% of SN 200 mineral oil) or without the 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. The above-mentioned adjuvant (Atpolan 80 EC) was chosen based on the recommendation of the Institute of Plant Protection as an agent intended for use in a wide group of crops.

Winter wheat, *Triticum aestivum* 'Muza', was grown after vetch grown for seed. Tillage for wheat was done following good agricultural practices. Mineral fertilization in kg of nutrient per hectare was as follows: 100 kg N × ha^{-1}; 40 kg P × ha^{-1}; 110 kg K × ha^{-1}. The whole experiment was sprayed with herbicides – sulphonylurea (Apyros 75 WG, 20 g × ha^{-1}) and fluroxypyr (Starane 250 EC, 250 g × l^{-1}, at a rate of 0.6 l × ha^{-1}), at the full tillering stage of winter wheat (BBCH 29–30).

Weed infestation of the winter wheat crop was determined based on the numbers, air-dry weight and species composition of weeds per 1m^2 during the study years. Weed infestation was evaluated by the dry-weight-rank method a week before expected harvest of the winter wheat crop. For this purpose, a 0.5 m^2 frame was used which was placed randomly in each plot twice. Names of weed species followed M i r e k 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). 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 =0.05. Constancy classes, which followed Braun-Blanquet (1964), were determined based on a 3-year analysis of weed infestation of winter wheat crops performed before the harvest of each crop.

RESULTS

Weed infestation of the winter wheat crop, expressed by the number of weeds per 1m^2 (Table 1) and air-dry weight produced by them (Table 2), was highly significantly differentiated by weather conditions during the study years, but it was less differentiated by growth regulators used. The year 2005 was most favourable for the occurrence of weeds in great numbers in the winter wheat crop – 166.8 plant × m^{-2}, whereas the year 2006 was the least favourable – 5.4 plant × m^{-2}. The situation with weed biomass production was similar, as it was the highest in 2005 – 65.75 g × m^{-2} and the lowest in the second year of the study – 1.42 g × m^{-2}.

The number of weeds in the winter wheat crop was also observed to be significantly dependent on retardants used. The highest number of weed individuals was recorded in the control plots (without retardant) – 96.3 plant·m^{-2}. Among the treatments with retardants, the lowest number of weeds was found in the plots sprayed with the retardant Moddus 250 EC – 64.0 plant × m^{-2}, followed by those where the growth regulator Antywylegacz Płynny 675 SL was used – 67 plant·m^{-2}. The application of the retardant Cecefon 465 SL resulted in the number of weeds of 77.8 plant × m^{-2}. This means that this latter growth regulator did not change significantly weed density per 1 m^2 of the winter wheat plots compared to both the control plots and the plots sprayed with the retardants.

The application of the adjuvant did not change significantly the number of weeds in the winter wheat crop. Nevertheless, it should be noted that the adjuvant Atpolan 80 EC used in combination with the retardants caused a clear decreasing trend in the number and weight of weeds only in the case of Antywylegacz Płynny 675 SL and Cecefon 465 SL (Tables 1 and 2). An opposite effect was obtained in the case of the retardant Moddus 250 EC, although the adjuvant Atpolan 80 EC had a clear beneficial effect, in combination with this compound, on the crop height of winter wheat stems (Table 3).

Weeds growing in the plots without retardant (control treatment) produced a weight of 28.26 g × m^{-2}. This value proved to be the lowest in the experiment, while compared to the growth regulator Cecefon 465 SL it was also significantly lower. Taking into consideration only the plots with retardants, it was found that weeds in the plot sprayed with Antywylegacz Płynny 675 SL produced the lowest average weight – 34.34 g × m^{-2}, whereas it was the highest in the treatment with the retardant Cecefon 465 SL – 41.68 g × m^{-2} (Table 2). However, the differences in weed weight between these treatments were within the limits of the experimental error.

Winter wheat plant height was significantly differentiated by all experimental factors, but to the greatest extent by growth regulators used (Table 3). On average for the three-year study period, the longest wheat stems (92.3 cm) were recorded in the control treatment (without retardant). All the retardants used significantly shortened wheat stem length and the retardant Cecefon 465 SL shortened it most of all (by 20.7%). This fact was translated into the highest dry weight of weeds and a distinctly higher number of weeds under the conditions of application of Cecefon 465 SL compared to the other retardants. The lowest retarding effect, though it was also significant, was found in the plots where the retardant Antywylegacz Płynny 675 SL was used – 76.8 cm. Winter wheat plant height changed in particular seasons of the study at a level of 13.8%. Significantly lower plants developed in each successive year of the study. The study found a statistically proven positive effect of the adjuvant on reducing winter wheat stem length. The difference between treatments in favour of the one with adjuvant was 5.5% (Table 3).

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

Treatments	Rate l × ha^{-1}	Mean for adjuvant		Mean for years			Mean
		a	b	2005	2006	2007	
Without retardant		96.3		223.0	6.0	60.0	96.3
Antywylegacz Płynny 675 SL	2.0	75.0	59.0	134.0	4.5	62.5	67.0
Moddus 250 EC	0.4	53.6	74.3	136.5	5.0	50.5	64,0
Cecefon 465 SL	2.0	84.6	71.0	173.5	6.0	54.0	77.8
Mean for adjuvant		77.4	75.2	166.8	5.4	56.8	76.3
LSD $_{(L=0.05)}$ between:		years			9.23		
		adjuvants			n.s.		
		treatments			22.70		
		years x treatments			44.20		

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

Table 2
Air-dry weight of weeds in the winter wheats crop (g × m^{-2})

Treatments	Rate l × ha^{-1}	Mean for adjuvant		Mean for years			Mean
		a	b	2005	2006	2007	
Without retardant		28.26		34.96	2.26	47.58	28.26
Antywylegacz Płynny 675 SL	2.0	38.32	30.35	69.14	1.73	32.15	34.34
Moddus 250 EC	0.4	36.04	42.76	75.10	0.40	42.70	39,40
Cecefon 465 SL	2.0	46.11	37.25	83.80	1.28	39.97	41.68
Mean for adjuvant		37.18	34.65	65.75	1.42	40.60	35.92
LSD $_{(L=0.05)}$ 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

Table 3
Winter wheat plant height (cm)

Treatments	Rate $l \times ha^{-1}$	Mean for adjuvant		Mean for years			Mean
		a	b	2005	2006	2007	
Without retardant		92.3		99.8	92.9	84.3	92.3
Antywylegacz Płynny 675 SL	2.0	79.6	74.0	80.7	80.7	68.9	76,8
Moddus 250 EC	0.4	80.4	72.1	78.8	83.0	66.8	76,2
Cecefon 465 SL	2.0	75.2	71.1	76.8	73.2	69.5	73,2
Mean for adjuvant		81.9	77.4	84.0	82.4	72.4	79.6
LSD $_{(L=0.05)}$ between:		years			0.96		
		adjuvants			0.66		
		retardants			2.38		
		years x retardant			4.62		
		years x adjuvant			1.66		

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

In the winter wheat crop, 25 weed species were found to occur in the plots with retardants and without adjuvant (Table 4) and 4 species less in the plots with retardants and with adjuvant (Table 5). Most weed taxa reached the number less than 1 plant·m^{-2} in the crop row. Therefore, 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 yield of the crop plant in question. Annual weeds such as: *Veronica persica, Apera spica-venti,* and *Viola arvensis*, dominated by far in the control treatment (without retardant) and in the plots with retardants. This means that the herbicides Apyros 75 WG and Starane 250 EC applied at the full tillering stage of winter wheat were the least effective against these species. Additionally, *Veronica arvensis, Echinochloa crus-galli, Capsella bursa-pastoris*, and *Chenopodium album*, reached significant numbers, that is, more than 1 plant × m^{-2}, in the control plots and generally also 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.

Analysing the effect of the retardants used on phytosociological constancy of weeds in the winter wheat crop, it was found that both in the plots without adjuvant and with adjuvant application the following 3 species were constant components of this agricultural ecosystem (class IV): *Chenopodium album* in the treatment with Antywylegacz Płynny 675 SL, *Veronica persica* and *Viola arvensis* in the treatment with the retardant Moddus 250 EC as well as *Veronica persica* in the plot treated with Cecefon 465 SL – (Tables 6 and 7). *Veronica persica* (class IV), *Chenopodium album* (class IV), and *Capsella bursa-pastoris* (class III) reached equally high constancy in the control plot (Table 7). A numerous group of taxa was recorded in constancy class III, i.e. a class that includes species found with a frequency of at least 40%. The following species: *Veronica persica, Viola arvensis, Chenopodium album, Capsella bursa-pastoris*, and *Elymus repens*, were included in this class in the plots with retardants but without adjuvant, while in the treatments with retardants and with adjuvant the following species were additionally noted: *Echinochloa crus-galli* and *Matricaria maritima subsp. inodora.* The other species, observed in constancy class I or II, were loosely associated with the agrocenosis in question, since they inhabited it only in about 20% of identifications at the most. The adjuvant Atpolan 80 EC used in the experiment did not affect significantly the changes in the weed community inhabiting the winter wheat crop. It only reduced the occurrence of the species inhabiting the wheat crop recorded in the lowest constancy classes (I and II).

Table 4

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

Species		Treatments			
		Control	Antywylegacz Płynny 675 SL	Moddus 250 EC	Cecefon 465 SL
I. Annuals					
1.	*Veronica persica* POIR.	18.9	21.6	20.0	19.1
2.	*Apera spica-venti* (L.) P. BEAUV.	53.4	23.7	13.3	43.6
3.	*Viola arvensis* MURRAY	9.9	15.4	10.4	12.4
4.	*Veronica arvensis* L.	3.0	0.0	3.6	2.3
5.	*Echinochloa crus-galli* (L.) BEAUV.	2.1	0.0	0.0	0.0
6.	*Capsella bursa-pastoris* (L.) MEDIK.	1.9	5.0	2.4	2.2
7.	*Chenopodium album* L.	1.8	2.0	1.0	1.6
8.	*Stellaria media* (L.) VILL	0.0	2.2	0.0	0.0
9.	*Galium aparine* L.	0.0	0.0	0.0	0.0
10.	*Geranium pusillum* BURM. F. EXL.	0.0	0.0	0.0	0.0
11.	*Matricaria maritima subsp. inodora* L.	0.0	0.0	0.0	0.0
12.	*Papaver rhoeas* L.	0.0	0.0	-	0.0
13.	*Lamium amplexicaule* L.	0.0	-	-	-
14.	*Fallopia convolvulus* (L.) Á. LÖVE	0.0^x	-	-	-
15.	*Polygonum persicaria* L.	-	0.0	0.0	0.0
16.	*Galinsoga parviflora* CAV.	-	0.0	-	0.0
17.	*Myosotis arvensis* (L.) HILL	-	0.0	0.0	-
18.	*Lapsana communis* L. S. STR.	-	0.0	-	-
19.	*Avena fatua* L.	-	0.0	-	-
20.	*Plantago intermedia* GILIB.	-	-	0.0	-
21.	*Galinsoga ciliata* (RAF.) S.F. BLAKE	-	-	-	0.0
Number of weeds plant × m^{-2}		95.3	71.4	52.0	82.2
Number of weed species		14	17	14	15
II. Perennials					
1.	*Elymus repens* (L.) GOULD	0.0	1.2	0.0	0,0
2.	*Equisetum arvense* L.	0.0	0.0	-	0,0
3.	*Cirsium arvense* (L.) SCOP.	-	0.0	0.0	-
4.	*Taraxacum officinale* F.H.WIGG.	-	0.0	-	0,0
Number of weeds plant × m^{-2}		0.0	3.6	0.0	0.0
Number of weed species		2	4	2	3
Total number of weeds I+II		96.3	75.0	53.6	84.6
Total number of weed species I+II		16	21	16	18

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

Table 5
Number of weed species per 1 m² in the winter wheat crop depending on retardants used, with adjuvant (mean for 3 years)

Species		Treatments			
		Control	Antywylegacz Płynny 675 SL	Moddus 250 EC	Cecefon 465 SL
I. Annuals					
1.	*Veronica persica* POIR.	18.9	17.1	14.4	18.9
2.	*Apera spica-venti* (L.) P. BEAUV.	53.4	12.5	31.0	25.2
3.	*Viola arvensis* MURRAY	9.9	12.2	13.9	14.7
4.	*Veronica arvensis* L.	3.0	6.1	7.7	4.9
5.	*Echinochloa crus-galli* (L.) P. BEAUV.	2.1	0.0	0.0	0.0
6.	*Capsella bursa-pastoris* (L.) MEDIK	1.9	0.0	2.0	2.1
7.	*Chenopodium album* L.	1.8	1.1	2.0	1.5
8.	*Fallopia convolvulus* (L.) Á. LÖVE	0.0^x	-	-	0.0
9.	*Stellaria media* (L.) VILL	0.0	0.0	-	0.0
10.	*Lamium amplexicaule* L.	0.0	-	-	-
11.	*Galium aparine* L.	0.0	0.0	0.0	0.0
12.	*Geranium pusillum* BURM. F. EXL.	0.0	-	-	0.0
13.	*Matricaria maritima* subsp. *inodora* L.	0.0	0.0	0.0	0.0
14.	*Papaver rhoeas* L.	0.0	-	0.0	-
15.	*Myosotis arvensis* (L.) HILL	-	0.0	0.0	-
16.	*Melandrium album* (MILL.)	-	0.0	-	-
17.	*Conyza canadensis* (L.) CRONQUIST	-	0.0	-	-
18.	*Lapsana communis* L. S. STR.	-	-	0.0	-
Number of weeds plant·m^{-2}		95.3	56.2	71.9	67.9
Number of weed species		14	13	12	12
II. Perennials					
1.	*Elymus repens* (L.) GOULD	0.0	1.2	0.0	1.5
2.	*Equisetum arvense* L.	0.0	0.0	0.0	0,0
3.	*Taraxacum officinale* F.H.WIGG	-	0.0	0.0	0.0
Number of weeds plant·m^{-2}		0.0	1.2	0.0	1.5
Number of weed species		2	3	3	3
Total number of weeds I+II		96.3	59.0	74.3	71.0
Total number of weed species I+II		16	16	15	15

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

Table 6
Constancy of weeds in the winter wheat crop in the plots without adjuvant
(mean for 3 years)

Species		Treatments			
		Control	Antywylegacz Płynny 675 SL	Moddus 250 EC	Cecefon 465 SL
I. Annuals					
1.	*Veronica persica* POIR.	IV	III	IV	IV
2.	*Chenopodium album* L.	IV	IV	II	III
3.	*Capsella bursa-pastoris* (L.) MEDIK.	IV	III	II	II
4.	*Viola arvensis* MURRAY	III	III	III	III
5.	*Apera spica-venti* (L.) P. BEAUV.	III	II	II	II
6.	*Veronica arvensis* L.	II	II	II	II
7.	*Stellaria media* (L.) VILL	II	II	II	II
8.	*Echinochloa crus-galli* (L.) BEAUV.	II	II	I	-
9.	*Galium aparine* L.	I	II	I	II
10.	*Papaver rhoeas* L.	I	I	I	I
11.	*Lamium amplexicaule* L.	I	-	-	-
12.	*Fallopia convolvulus* (L.) Á. LÖVE	I	-	-	-
13.	*Geranium pusillum* BURM. F. EXL.	-	II	II	I
14.	*Matricaria maritima subsp. indora* L.	-	II	II	II
15.	*Galinsoga parviflora* CAV.	-	II	-	I
16.	*Polygonum persicaria* L.	-	I	I	I
17.	*Myosotis arvensis* (L.) HILL	-	I	I	-
18.	*Lapsana communis* L. S. STR.	-	I	-	-
19.	*Avena fatua* L.	-	I	-	-
20.	*Plantago intermedia* GILIB.	-	-	I	-
21.	*Galinsoga ciliata* (RAF.) S.F. BLAKE	-	-	-	I
Number of weed species IV		3	1	1	1
in constancy classes (C) III		2	3	1	2
II		3	8	7	7
I		4	5	6	5
II. Perennials					
1.	*Elymus repens* (L.) GOULD	II	II	II	III
2.	*Equisetum arvense* L.	II	II	-	II
3.	*Cirsium arvense* (L.) SCOP.	I	II	-	-
4.	*Taraxacum officinale* F.H.WIGG.	-	I	-	-
Number of weed species IV		-	-	-	-
in constancy classes (C) III		-	-	-	1
II		2	3	1	1
I		1	1	-	-

- - the species did not occur

Table 7
Constancy of weeds in the winter wheat crop in the plots with adjuvant (mean for 3 years)

Species	Treatments			
	Control	Antywylegacz Płynny 675 SL	Moddus 250 EC	Cecefon 465 SL
I. Annuals				
1. *Veronica persica* POIR.	IV	III	IV	IV
2. *Chenopodium album* L.	IV	III	II	III
3. *Capsella bursa-pastoris* (L.) MEDIK	IV	II	II	II
4. *Viola arvensis* MURRAY	III	III	IV	III
5. *Apera spica-venti* (L.) P. BEAUV.	III	II	II	II
6. *Veronica arvensis* L.	II	II	II	II
7. *Stellaria media* (L.) VILL	II	I	-	II
8. *Echinochloa crus-galli* (L.) P. BEAUV.	II	III	II	II
9. *Galium aparine* L.	I	I	II	I
10. *Papaver rhoeas* L.	I	-	I	-
11. *Lamium amplexicaule* L.	I	-	-	-
12. *Fallopia convolvulus* (L.) Á. LÖVE	I			I
13. *Matricaria maritima* subsp. *inodora* L.	-	I	III	II
14. *Myosotis arvensis* (L.) HILL	-	I	I	-
15. *Conyza canadensis* (L.) CRONQUIST	-	I	-	-
16. *Poa Anna* L.	-	I	-	-
17. *Lamium purpureum* L.	-	-	-	I
18. *Lapsana communis* L. S. STR.	-	-	II	-
Number of weed species IV	3	-	2	1
in constancy classes (C) III	2	4	1	2
II	3	3	7	6
I	4	6	2	3
II. Perennials				
1. *Elymus repens* (L.) GOULD	II	II	II	III
2. *Equisetum arvense* L.	II	I	-	-
3. *Cirsium arvense* (L.) SCOP	I	-	-	-
4. *Taraxacum officinale* F.H.WIGG	-	I	I	I
Number of weed species IV	-	-	-	-
in constancy classes (C) III	-	-	-	1
II	2	1	1	-
I	1	2	1	1

- - the species did not occur

DISCUSSION

Excessive weed infestation of the crop is one of the factors reducing crop plant height and yield quality (A d a m c z e w s k i , 2000; W e s o ł o w s k i and W o ź n i a k , 2001). Winter cereals, due to their longer growing period, generally create greater freedom of growth for the weed flora than spring cereals. This statement applies to floristic richness, phenological aspects, and overall weed infestation (H o c h ó ł , 2003; B e r e s , 2010). In the study of B u j a k (1996), the number and weight of weeds were dependent on the type and number of tillage treatments. In the opinion of B u r a c z y ń s k a and C e g l a r e k (2008), the previous crop had a significant effect on the number and dry weight of weeds in the winter wheat crop. In reducing weed infestation, Korres and Froud-Williams (2002) draw attention to plant density per unit area in addition to the morphological characters. In their opinion, increased plant density reduces the penetration of solar radiation within the crop canopy, which has an inhibiting effect on weed infestation of fields. In the present study, the number and dry weight of weeds varied most of all by year (by 96.7%). The significantly highest number of weeds in the winter wheat crop was recorded in the year 2005 which was characterized by higher than average total rainfall and mean air temperature. In the other drier years, this number was three or four times lower. The growth regulators used modified significantly weed infestation of winter wheat, at a level of 17.7%. The influence of weather conditions during the growing season on the number and dry weight of weeds in the winter wheat crop has also been proved by Wesołowski et al. (1993) and Smatana et al. (2010).

Agricultural practices used in crop cultivation can result in reduced or increased weed infestation (Dastgheib et al. 1999; Szeleźniak et al. 2007). Retardants, as agents that increase the resistance of cereals to lodging, shorten cereal stems by reducing the length of their individual internodes (Cox and Otis, 1989). The present study showed a positive effect of retardant treatments on winter wheat plant height. 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 11.6 cm compared to the first year. Similar results have been obtained by Adamczewski and Praczyk (1997), Łęgowiak and Wysmułek (2000) as well as Pietryga and Drzewiecki (2003). The above-mentioned authors obtained a significant (12–18.5%) reduction in cereal plant height as influenced by the retardants Moddus 250 EC and Antywylegacz Płynny 675 SL, but only under favourable weather conditions.

The results of the present study show that stem shortening had a positive effect on reducing the total number of weeds in the crop in each year of the study. All the growth regulators used reduced weed density in winter wheat, but this reduction was the highest in the case of Moddus 250 EC and Antywylegacz Płynny 675 SL. In turn, the greater increase in biomass compared to the number of weeds proves that a less dense cereal crop not only promoted emergence of weeds, but also supported their luxuriant growth. Skrzyczyńska and Pawlonka (2004) also found a reduction in weed infestation of a winter triticale crop as influenced by retardants at a lower level of N (50 kg × ha^{-1}).

The knowledge of the floristic composition of weed communities and dominant species in winter wheat crops plays a key role in planning treatments designed to reduce weed infestation (Skrzyczyńska and Pawlonka, 1999). The weed community in the plots analysed in the present study included a total of 25 weed species in the treatments without adjuvant and 21 species in the treatments with adjuvant. The taxa that were found in greatest numbers in both above-mentioned variants were as follows: *Veronica persica, Apera spica-venti, Viola arvensis, Veronica arvensis, Echinochloa crus-galli*, and *Chenopodium album.* Moreover, the following reached high numbers: *Stellaria media* and *Elymus repens* in the treatment with Antywylegacz Płynny 675 SL, *Capsella bursa-pastoris* in the treatment with the retardant Moddus 250 EC, and *Capsella bursa-pastoris* in the plot treated with Cecefonem 465 SL.

The adjuvant Atpolan 80 EC used in the experiment only slightly affected the weed community inhabiting the winter wheat plots. As a consequence, all species maintained similar constancy in the treatments compared. However, the effect of the adjuvant on reducing the level of weed infestation, as measured by the number and dry weight of weeds in the crop row, was found to show a positive trend. Similar results were obtained in the study of Kwiatkowski and Wesołowski (2011). The above-mentioned authors observed a significant reduction in the number of weeds in the crop by respectively 45% (Atpolan 80 EC), 39% (Break Thru S 240), and 34% (ammonium sulphate). The adjuvants used also had a significant effect on reducing the weight of weeds in the crop compared to the control treatment, as this weight was reduced more than twice.

CONCLUSIONS

1. Weed density and biomass in winter wheat crops showed great variation between years. The wet year of 2005 favoured the occurrence of weeds in great numbers and with the highest weight, while the dry and warm year of 2006 promoted their occurrence in small numbers. But meteorological conditions affected the species richness of the weed community to a lesser extent.
2. All the growth regulators used reduced the numbers of weeds in the winter wheat crop, but Moddus 250 EC and Antywylegacz Płynny 675 SL to the greatest extent.
3. Among the retardant tested, Cecefon 465 SL reduced winter wheat plant height the most, while Moddus 250 EC and Antywylegacz Płynny 675 SL to a lesser extent. A lower number and dry weight of weeds in the crop were recorded in the plots with the two latter agents compared to the treatment with Cecefon 465 SL.

4. A trend was observed towards a reduction in the number of weeds and an increase in weed weight in winter wheat as a result of the addition of the adjuvant Atpolan 80 EC. This agent only slightly affected the species composition and phytosociological constancy of the weed community.
5. The following species showed higher constancy (constancy class IV) in all the experimental treatments: *Veronica persica, Chenopodium album, Viola arvensis*, and *Capsella bursa-pastoris,* whereas *Echinochloa crus-galli, Apera spica-venti*, and *Matricaria maritima subsp. inodora* also reached constancy class III in some treatments.

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Authors' contributions

The following declarations about authors' contributions to the research have been made: designing the experiments: MW, EH; field work: EH; data analyses: EH, writing the manuscript: EH.

REFERENCES

Adamczewski K. 2000. Rozwój metod zwalczania i perspektywy ograniczania chwastów. / Weed control method development and perspectives of reduction of weed density. Prog. Plant Protection / Post. Ochr. Roślin 40 (1): 101–111. (in Polish)

Adamczewski K., Praczyk T. 1997. Regulatory wzrostu i rozwoju roślin. / Growth regulators and plant growth. PWN (L. Jankiewicz ed.), 167–177 (in Polish).

Anjum T., Bajwa R. 2010. Competition losses caused by *Rumex dentatus* L. and *Chenopodium album* L. in wheat (*Triticum aestivum* L.). Philipp. Agricul. Sci: 93 (3): 365–368.

Beres B.L., Harker K.N., Clayton G.W., Bremer E., Blackshaw R.E., Graf R.J. 2010. Weed-competitive ability of spring and winter cereals in the Northern Great Plains. Weed Tech. 24 (2): 108–116. http://dx.doi.org/10.1614/WT-D-09-00036.1

Bujak K. 1996. Plonowanie i zachwaszczenie roślin 4–polowego płodozmianu w warunkach uprawy roli na erodowanej glebie lessowej. II. Jęczmień jary. / Yielding and weed infestation of plants in 4-plot rotation in the conditions of simplified cultivation on the eroded less soil. II. Spring barley. Ann. UMCS, Sect. E 51: 19–23. (in Polish)

Buraczyńska D., Ceglarek F. 2008. Wpływ przedplonu na zachwaszczenie pszenicy ozimej. / Impact of previous crop on winter wheat weed infestation. Prog. Plant Protection/Post. Ochr. Roślin. 48 (4): 1407–1411. (in Polish)

Braun-Blanquet J. 1964. Pflanzensoziologie. Grundzüge der Vegetationskunde. 3. Aufl. Springer-Verlag, Wien-New York: ss. 865. (in German)

Cox W.J., Otis D.J. 1989. Growth and yield of winter wheat as influenced by chlormequat chloride and ethephon. Agron. J. 81: 264–270. http://dx.doi.org/10.2134/agronj1989.00021962008100020025x

Dastgheib F., Kumar K., Goh K.M. 1999. Weed infestations in wheat cropping systems as affected by crop residues and their management practices. Biological Agriculture & Horticulture: Int. J. Sustan. Prod. Syst. 16 (4): 395–407. http://dx.doi.org/10.1080/01448765.1999.9755242

Gaskin R.E., Murray R. J., Krishna H., Car -penter A. 2000. Effect of adjuvants on the retention of insecticide spray on cucumber and pea foliage. New Zeal Plant Prot. 53: 355–359.

Hochół T. 2003. Chwasty czy rośliny towarzyszące roślinom? / Weeds or plants accompanying crops? Pam. Puł. 134: 89–96. (in Polish)

Kierzek R., Głowacki G. 2004. Łączne stosowanie regulatorów wzrostu Moddus 250 EC i Antywylegacz Płynny 675 SL w pszenicy ozimej. / Application of plant growth regulators Moddus 250 EC and Antywylegacz Płynny 675 SL in winter wheat. Progr. Plant Protection/Post. Ochr. Roślin 44(2): 823–827. (in Polish)

Korres N.E., Froud-Williams R.J. 2002. Effect of winter wheat cultivars and seed rate on biological characteristics of naturally occurring weed flora. Weed Res. 42 (6): 417–428. http://dx.doi.org/10.1046/j.1365-3180.2002.00302.x

Kwiatkowski C., Wesołowski M. 2011. Wpływ adiuwantów oraz zredukowanych dawek środków ochrony roślin na zachwaszczenie pszenicy ozimej / Effect of adjuvants and reduced doses of pesticides on weed infestation in winter wheat. Progr. Plant Protection/Post. Ochr. Roślin 51 (1): 348–353 (in Polish).

Łęgowiak Z., Wysmułek A. 2000. Stosowanie regulatorów wzrostu w zbożach. / Application of plant growth regulators in cereals. Progr. Plant Protection/Post. Ochr. Roślin 40 (2): 932–934 (in Polish).

Mirek Z., Piękoś-Mirkowa H., Zając A., Zając M. 2002. Flowering plants and pteridophytes of Poland. W. Szafer Institute of Botan, Polish Academy of Sciences.

Pietryga J., Drzewicki S. 2003. Wpływ regulatora Moddus 250 EC na wzrost, plonowanie i wybrane cechy technologiczne ziarna pszenicy ozimej. / Effect of the growth regulator Moddus 250 EC on growth, yield and some technological characteristics of winter wheat grain. Progr. Plant Protection/Post. Ochr. Roślin 43 (2): 857–862. (in Polish)

Rajala A., Peltonen-Sainio P. 2001. Grain and oil crops: Plant growth regulator effects on spring cereal root and shoot growth. Agron. J. 93: 936–943.

Skrzyczyńska J., Pawlonka Z. 1999. Zachwaszczenie pszenicy ozimej na Nizinie Południowopodlaskiej. / Weed infestation of winter wheat in the South Podlasie Lowland. Pam. Puł. 118: 375–382. (in Polish)

Skrzyczyńska J., Pawlonka Z. 2004. Wpływ stosowania retardantu wzrostu na wschody i rozwój chwastów w pszenżycie ozimym w warunkach zróżnicowanego nawożenia azotowego. / Effect of growth retardant on weed sprouting and development in winter triticale under different levels of nitrogen fertilisation. Acta Sci. Pol. Agricultura 3 (2): 61–67. (in Polish)

Smatana J., Vereš T., Smatanová N., Kobulnický P. 2010. Weed infestation dynamics in the winter wheat (*Triticum aestivum* l.) canopy. Res. J. Agric. Sci. 42 (1): 275–278.

Szeleźniak E., Grabiński J., Nieróbca P. 2007. Zachwaszczenie trzech gatunków zbóż uprawianych w płodozmianie zbożowym w zależności od stopnia intensywności technologii produkcji. / Weed infestation of three grain species cultivated under cereal crop rotation and three technologies varying in production intensity. Prog. Plant Protection/Post. Ochr. Roślin 47 (3): 276–279. (in Polish)

Wesołowski M., Gregorczyk K., Woźniak A. 1993. Następczy wpływ plantacji nasiennych traw na plonowanie i zachwaszczenie pszenicy ozimej. Cz. II. Zachwaszczenie pszenicy. / The consequent effect of a seeded grass plantation on yield and weed infestation of winter wheat. II. Weed infestation of wheat. Rocz. Nauk Roln. Seria A 109 (4): 183–189. (in Polish)

Wesołowski M., Woźniak A. 2001. Zachwaszczenie aktualne i potencjalne zbóż jarych w różnych systemach następstwa roślin. / Present and potential weed infestation of spring cereals in different cropping system. Acta Agrobot. 54 (1): 175–190 (in Polish).

Zachwaszczenie łanu pszenicy ozimej (*Triticum aestivum* L.) w warunkach stosowania niektórych retardantów

Streszczenie

W pracy przedstawiono zależność pomiędzy stosowaniem zabiegu skracania zbóż preparatami Antywylegacz Płynny 675 SL, Modus 250 EC i Cecefon 465 SL a zachwaszczeniem. Retardanty stosowano w fazie 1-ego kolanka (BBCH 31 – Antywylegacz Płynny 675 SL) oraz 2-ego kolanka pszenicy ozimej (BBCH 32 – Moddus 250 EC i Cecefon 465 SL) z adiuwantem Atpolan 80 EC (75% oleju mineralnego SN 200) lub bez adiuwanta. Pszenicę ozimą odmiany 'Muza' wysiewano w stanowisku po wyce siewnej, uprawianej na nasiona. Całość doświadczenia opryskiwano herbicydami – Apyros 75 WG i Starane 250 EC w fazie pełni krzewienia (BBCH 29–30). Obiekt kontrolny stanowiły poletka, na których nie stosowano regulatorów wzrostu.

Zagęszczenie i biomasa chwastów wykazywały dużą zmienność w latach badań. W łanie pszenicy ozimej dominowały: *Veronica persica, Viola arvensis, Veronica arvensis, Capsella bursa-pastoris* i *Chenopodium album* z klasy roślin dwuliściennych oraz z klasy roślin jednoliściennych *Apera spica-venti*, *Echinochloa crus-galli i Elymus repens.* Poziom zachwaszczenia łanu pszenicy ozimej mierzony liczbą i powietrznie suchą masą chwastów istotnie różnicowały lata badań, zastosowane retardanty oraz interakcje tych czynników. Adiuwant Atpolan 80 EC nie wpływał istotnie na wymienione parametry zachwaszczenia.