ACTA SCIENTIARUM POLONORUM *Acta Sci. Pol., Agricultura 9(3) 2010, 3-12*

WEED INFESTATION AND YIELD OF SPRING CEREAL MIXTURES DEPENDING ON CULTIVATION METHOD

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Abstract. In 2005-2007 at the Education and Research Station Krasne (50°03' N; 22°06' E) near Rzeszów, on brown soil formed from loess classified as the good wheat complex, a study was carried out on the effect of cultivation methods on the weed infestation and yield of two-species mixtures with 50% of spring wheat, spring barley and oat. The mechanical and chemical method using harrowing and ½ dose of the herbicide Chwastox Trio 540 SL was characterized by the highest effectiveness in limiting the total number and mass of weeds, especially in the oat-barley mixture. Applying each method of cultivation resulted in a significant increase in the mixture grain yield as compared with the control treatment. Significantly lower grain yields were obtained on the treatments after the application of harrowing and the full dose of the herbicide as compared with the herbicide application at a smaller dose after earlier harrowing. The oat-barley mixture was characterized by a higher yield-forming potential. Its yield amounted to 4.42 $t \cdot ha^{-1}$ and was significantly higher, on average by 0.45 $t \cdot ha^{-1}$, than the yield of the other mixtures.

Key words: barley, Chwastox Trio, harrowing, oat, weed control, wheat

INTRODUCTION

One of the basic tasks in production of cereal crops is a reduction in the harmfulness of weed infestation of plantations, which can be achieved among others by the application of proper crop rotation and herbicidal protection, and in the case of cereal mixtures, by the proper selection of species and cultivars for the mixture components.

As far as limiting weed infestation is concerned, mixed stands of cereals, in comparison with one-species crops, have more adaptation and competitive abilities, better space utilization, as well as complementary using of habitat resources and consequently, reducing those resources for weeds occurring there [Wanic and Hruszka 2000, Parylak et al. 2006]

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In spite of the fact that plants in intervarietal or interspecific mixed stands are less infested by weeds than pure sowings, in cereal mixtures, especially those without oat, the problem of excessive weed infestation appears, as well as the need for weed control [Rudnicki et al. 1996]. Well managed crop protection against weed infestation requires the application of various mutually complementing methods and techniques of weed harmfulness reduction in a possibly integrated way. Especially the combined mechanical and chemical methods with the use of minimal doses of herbicides are used as an element of plant protection.. Their advantage is limiting the pollution of the environment and plant products with remains of active substances and quite good weeding effectiveness, at undoubtedly lower costs of chemical weed control [Starczewski and Żądełek 2000, Kierzek and Wachowiak 2004].

The aim of this study was to assess the effect of different methods of cultivation on the weed infestation and yield of two-species mixtures with spring wheat, spring barley and oat.

The working hypothesis assumed says that applying mechanical and chemical cultivation will limit weed infestation more effectively and will result in an increase in yield of two-species mixtures with 50% of spring wheat, spring barley and oat, as compared with postemergence harrowing or the application of the full dose of a herbicide.

MATERIAL AND METHODS

The study was carried out over 2005-2007 under conditions of the Rzeszowskie foothills at an experimental plot in Krasne (50°03' N; 22°06' E), owned by the Didactic and Research Station of the Faculty of Biology and Agriculture of the University of Rzeszów.

The experiment was located on brown soil formed from loess, classified as the quality class III a, the good wheat complex, with the content of N – 0.15%, P_2O_5 – 220 mg·kg^{-1} soil, K_2O – 150 mg·kg^{-1} soil and pH = 6.5. The experiment was established with the randomized complete block design in four replications, and the area of the plot for harvesting amounted to 15 m^2.

The experimental factors were:

– variants of two-species mixtures of spring wheat, spring barley and oat:
  A – wheat 50% + barley 50%,
  B – wheat 50% + oat 50%,
  C – oat 50% + barley 50%;
– cultivation methods:
  I – control treatment – without weed control,
  II – 2-time harrowing,
  III – Chwastox Trio 540 SL – 2.0 dm^3·ha^{-1},
  IV – 2-time harrowing + Chwastox Trio 540 SL – 1.0 dm^3·ha^{-1}.

The sowing rate of spring cereal mixture grains was determined in percentage in relation to the established standard of these species in pure sowing, which amounted to 550 pcs·m^{-2} for spring wheat, 350 pcs·m^{-2} for spring barley and 500 pcs·m^{-2} for oat. Winter wheat was the forecrop for the mixtures each time. Every year standard tillage and mineral fertilization was carried out after harvesting the forecrop.

Preemergence harrowing of spring cereal mixed stands was made at the beginning of tillering (13-15 BBCH) and several days later. The herbicide Chwastox Trio 540 SL both at the full and reduced dose was applied at the tillering stage of spring cereals (13-15 BBCH). Spraying of the mixtures was conducted using a knapsack sprayer with a pressure of 0.3 mPa and a velocity of about 4 $km \cdot h^{-1}$ using spray liquid in an amount of 300 $dm^3 \cdot h^{-1}$.

The analysis of weed infestation of the plant stand was carried out twice – at tillering phase (13-15 BBCH) before applying weed control measures (a – the first observation) and 3-4 weeks (37-39 BBCH) after their application (b – the second observation). The botanical-quantitative method showing the potential weed infestation of the mixtures was used to assess weed infestation during the first observation.

Another analysis of weed infestation after applying cultivation measures was conducted by the quantitative and gravimetric method, determining the species composition, number and air dry weight of weeds. At both times the assessment of weed infestation was carried out at two randomly selected places of each plot, using a frame of 0.5 x 0.5 m. The effectiveness of different cultivation methods on weeds in mixtures, including dominating species, was assessed by expressing the number of destroyed weeds in percentage in relation to the control treatment.

The yielding level of the spring cereal mixtures was also assessed. Grain yield from 1 ha was determined on the basis of harvesting from the plot after converting into 15% moisture.

The results were worked out statistically using the analysis of variance and Student's t-test, calculating the least significant difference at the level of significance 0.05. Statistical calculations were made using the program FR-ANALWAR 4.3.

The growing period of spring cereal mixtures in the years 2005-2007 was characterized by quite changeable climatic conditions. In 2005 and 2006 the total rainfall from April to August was 445.2 and 496.1 mm, respectively and was higher by 19.9 and 28.1% than the average total from the long-time period. As opposed to rainfall, average air temperatures in 2005 and 2006 were similar and amounted to 11.2 and 11.9^oC, at the average long-time air temperature 14.7^oC. The year 2007, in turn, was characterized by the highest average air temperature (16.5^oC) and the lowest amount of rainfall (346.5 mm). The average air temperature at that period was by 1.8^oC higher in comparison with the long-time period, and the total rainfall was lower by 10.1 mm (Table 1).

RESULTS AND DISCUSSION

The analysis of weed infestation carried out at tillering phase, as well as after applying various cultivation methods of spring cereal mixtures, indicated from 22 to 24 species of weeds, where the proportion of perennial species was small and ranged from 4 to 6. Those definitely dominating in the weed community were *Chenopodium album* L., *Viola arvensis* Murr., *Thlaspi arvense* L., *Capsella bursa-pastoris* L., as well as *Matricaria indora* L. and *Stellaria media* L. (Vill), which altogether accounted for about 72.8% of the spring population and 59.1% of the whole of weeds after mixture cultivation measures. Similar state of weed infestation of spring mixtures with a predominance of the above mentioned species and, additionally, *Anthemis arvensis* L., *Elymus repens* (L.) Gould, *Galium aparine* L. was reported in the study by Idziak and Michalski [2003] as well as Jakubiak and Gałęzewski [2007].

Table 1. Meteorological conditions during the study
Tabela 1. Warunki meteorologiczne w okresie badań

Year – Rok	Month – Miesiąc					Mean Średnia
	April kwiecień	May maj	June czerwiec	July lipiec	August sierpień	
Temperature – Temperatura, °C						
2005	8.4	12.6	16.6	18.6	18.4	11.2
2006	9.1	13.9	16.8	19.8	17.5	11.9
2007	8.9	16.3	18.5	19.9	19.0	16.5
Mean from 1972- 2004 Średnia z lat 1972-2004	8.4	13.2	16.5	18.0	17.6	14.7
Rainfall – Opady, mm						
2005	61.6	40.9	64.3	179.6	98.8	445.2
2006	48.4	105.1	109.6	109.1	123.9	496.1
2007	27.3	49.3	95.6	87.3	87.0	346.5
Mean from 1972- 2004 Średnia z lat 1972-2004	47.3	68.0	77.0	90.0	74.3	356.6

Of the cereal mixtures during the first observation, the smallest number of weed seedlings (112.9 pcs.·m^{-2}) was found in the oat-barley mixture, and slightly more (115.1 pcs.·m^{-2}) in the wheat-oat mixture (Table 1). Both mixtures rather effectively competed with weeds as compared with the wheat-barley mixture, where the average weed number amounted to 146.3 pcs.·m^{-2}, yet it was not confirmed statistically. Also the study by Wanic and Hruszka [2000] proves that the mixed sowing of cereals, especially oat with barley, may result in a reduction of weed infestation. Rudnicki et al. [1996] report that a mixture of those species may reduce weed infestation by about 20% as compared with their pure sowing. The study by Sobkowicz [1999], however, indicated that the number of weeds in a stand of oat-barley mixture did not differ significantly from the number of weeds in the pure sowings.

As in the case of the first observation, during the next assessment the tested variants of mixtures did not have a fundamental effect on the number of occurring weed species. On the control treatments, as compared with the first observation, a regulative role in limiting the number of weeds by 20.6 and 24.2% was confirmed in the case of mixtures B and C, and only by 14.0% for mixture A. Similar results were obtained by Jakubiak and Gałęzewski [2007] in experiments with tested species of spring cereals grown in pure sowings and mixtures not using weed control measures.

In the present study, the weed infestation of spring cereal mixtures expressed by the number of weeds was decreased significantly on all the cultivation treatments as compared with the control treatment (Table 2). On average during the experiment a reduction in the number of weeds ranged from 5.5-fold after the application of harrowing of mixtures to 8.8-fold after harrowing and applying the herbicide Chwastox Trio 540 SL in a dose of 1.0 dm^3·ha^{-1}. Application of the preparation Chwastox Trio 540 SL in the full recommended dose limited 6.4-fold the number of weeds as compared with the control. Good effectiveness of the mechanical and chemical method with the use of harrowing and ½ dose of the herbicide in weed control in cereals, especially as compared with ½ dose of the herbicides, is confirmed by the studies by Starczewski and Żądełek [2000] as well as Kierzek and Wachowiak [2004].

Table 2. Number of weed species on m^2
Tabela 2. Liczba gatunków chwastów na m^2

Cultivation method Sposób pielęgnacji	Mixture composition – Skład mieszanki						Mean – Średnia	
	A		B		C			
	a	b	a	b	a	b	a	b
I	142.3	122.3	120.1	95.3	103.2	78.2	121.9	98.6
II	155.3	23.2	119.2	16.2	110.1	14.6	128.2	18.0
III	135.3	19.6	105.3	14.3	120.1	12.5	120.2	15.5
IV	152.1	15.8	115.6	9.5	118.2	8.3	128.6	11.2
Mean – Średnia	146.3	45.2	115.1	33.8	112.9	28.4	124.7	35.8
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla:								
cultivation method – sposobu pielęgnacji			a ns – ni		b 32.0			
mixture – mieszanki			a ns – ni		b ns – ni			

A – wheat 50% + barley 50% – pszenica 50% + jęczmień 50%
B – wheat 50% + oat 50% – pszenica 50% + owies 50%
C – oat 50% + barley 50% – owies 50% + jęczmień 50%
a – the first observation – obserwacja pierwsza, b – the second observation – obserwacja druga
I – control treatment – without weed control – obiekt kontrolny – bez odchwaszczania
II – 2-time harrowing – 2-krotne bronowanie
III – Chwastox Trio 540 SL – 2.0 $dm^3 \cdot ha^{-1}$
IV – 2-time harrowing + Chwastox Trio 540 SL – 1.0 $dm^3 \cdot ha^{-1}$ – 2-krotne bronowanie + Chwastox Trio 540 SL – 1,0 $dm^3 \cdot ha^{-1}$
ns – ni – non-significant differences – różnice nieistotne

In the present study, an effect of the combined effect of cultivation methods and mixture variants on the weed lushness expressed by their air dry weight was observed (Table 3).

Table 3. Air dry weight and degree of weed control
Tabela 3. Powietrznie sucha masa i stopień zniszczenia chwastów

Cultivation method Sposób pielęgnacji	Mixture composition – Skład mieszanki			Mean Średnia
	A	B	C	
Air dry weight of weeds – Powietrznie sucha masa chwastów, $g \cdot m^{-2}$				
I ($g \cdot m^{-2}$)	55.3	39.4	25.1	39.9
II	23.8	13.2	10.6	15.8
III	19.6	15.3	9.8	14.9
IV	12.9	10.2	4.9	9.3
Mean – Średnia	27.9	19.5	12.6	–
$LSD_{0.05}$ – $NIR_{0,05}$ for – dla:				
cultivation method – sposobu pielęgnacji	4.2			
mixture – mieszanki	4.6			
interaction – interakcji	5.6			
Degree of total weed control – Stopień zniszczenia chwastów ogółem, %				
I ($szt. \cdot m^{-2}$)	101.3	95.3	78.2	91.6
II	67.1	71.4	83.1	73.9
III	70.7	73.1	85.0	76.3
IV	81.5	84.4	98.0	88.0

for explanations, see Table 2 – objaśnienia pod tabelą 2

After the application of harrowing and ½ dose of the preparation Chwastox Trio 540 SL the weight of weeds amounted to 9.3 $g \cdot m^{-2}$ and was significantly less, as compared with the

control and with the treatments with the application of only harrowing (15.8 g·m^{-2}) or only the herbicide (14.9 g·m^{-2}). Variants of the tested mixtures generally indicated a relation of air dry weight with the count of weeds. The stand of the oat-barley mixture (C) was characterized by a considerably smaller air dry weight (12.6 g·m^{-2}), whereas the largest weight of weeds (27.9 g·m^{-2}) was found in the wheat-barley mixture (A). Slightly different results were reported by Parylak et al. [1999], who obtained a larger dry weight of weeds in the oat-wheat mixture, and the smallest in the barley-wheat mixture, and the dry weight of weeds in the oat-barley mixture during its harvesting amounted to 19.3 g·m^{-2}.

In the present study, the weeding effectiveness of cultivation measures in relation to the total number of weeds ranged from 73.9% in the case of mechanical cultivation of mixtures to 88.0% on the treatment with mechanical and chemical weed control. The most noticeable limiting of the weed number of species dominating on all the cultivation treatments was observed in the oat-barley mixture (C) and the weakest in the wheat-barley mixture (A). Both the application of the preparation Chwastox Trio 540 SL in the full dose and two-time harrowing with a half of a dose of this herbicide effectively controlled *Thlaspi arvense* and *Chenopodium album,* whereas slightly worse *Viola arvensis* and *Capsella bursa-pastoris*. However, the two-time harrowing of the mixtures was characterized by a lower, but comparable, effectiveness (from 79.8 to 82.8%) in relation to these weed species (Table 4). Weed infestation of winter wheat depended not only on the experimental factors but also on the years of the study. Higher rainfall in 2005-2006, during the spring-summer growing period of the mixtures increased mainly the air dry weight of weeds as compared with 2007 (Tables 1 and 3). The proved effect of mostly rainfall on the weed infestation of spring cereals is shown among others in the studies by Woźniak [2003] and Piekarczyk [2005].

Table 4. Weed control effectiveness of major weed species
Tabela 4. Skuteczność zwalczania ważniejszych gatunków chwastów

Cultivation method Sposób pielęgnacji	Mixture composition Skład mieszanki	Weed control effectiveness – Skuteczność chwastobójcza, %			
		CHEAL	VIOAR	THLAR	CAPBP
I (szt.·m^{-2})	A	30.5	12.2	10.3	8.0
	B	25.1	14.5	9.2	7.5
	C	23.2	13.2	6.7	5.9
	mean – średnia	26.3	13.3	8.7	7.1
II	A	75.1	79.5	91.4	75.3
	B	79.7	78.5	75.6	78.9
	C	85.2	90.5	81.4	85.3
	mean – średnia	80.0	82.8	82.8	79.8
III	A	85.1	84.2	85.1	86.6
	B	94.4	93.1	89.5	89.3
	C	93.9	92.2	100	92.3
	mean – średnia	91.1	89.8	91.5	89.4
IV	A	85.2	86.1	95.2	82.4
	B	95.3	87.7	100	100
	C	100	96.7	100	95.2
	mean – średnia	93.5	90.2	98.4	92.5

for explanations, see Table 2 – objaśnienia pod tabelą 2
CHEAL – *Chenopodium album*, VIOAR – *Viola arvensis*, THLAR – *Thlaspi arvense*, CAPBP – *Capsella bursa-pastoris*

The yield of spring cereal mixtures was less diversified than the level of their weed infestation. The cultivation methods applied resulted in a significantly higher yield of the mixtures, as compared with the control treatment, on average after two-time harrowing by 15.6%, and after the application of the herbicide Chwastox Trio 540 SL by 18.4% (Table 5). The largest increase in grain yield – by 25.4% in relation to the control – was obtained on treatments after the application of harrowing and ½ dose of Chwastox Trio 540 SL. The study by Idziak et al. [2007] on the weed infestation and yield of mixtures with various proportion of oat and barley indicates that applying additional combined measures – in this case against diseases and pests – contributed to a significant increase in yield of these mixtures (by 3.5 $t \cdot ha^{-1}$) as compared with treatments weeded only mechanically or chemically.

Table 5. Grain yield depending on cultivation methods and mixture composition, $t \cdot ha^{-1}$
Tabela 5. Plon ziarna w zależności od sposobów pielęgnacji i składu mieszanki, $t \cdot ha^{-1}$

Cultivation method Sposób pielęgnacji	Year Rok	Mixture composition – Skład mieszanki			Mean Średnia
		A	B	C	
I	2005	3.50	3.45	3.73	3.56
	2006	3.68	3.53	3.95	3.72
	2007	3.45	3.32	3.65	3.47
Mean – Średnia		3,54	3.43	3.78	3.58
II	2005	3.95	4.12	4.29	4.12
	2006	4.30	4.21	4.85	4.45
	2007	3.65	3.75	4.18	3.86
Mean – Średnia		3,97	4.03	4.44	4.14
III	2005	4.05	4.21	4.46	4.24
	2006	4.35	4.15	4.99	4.50
	2007	3.82	3.92	4.22	3.99
Mean – Średnia		4,07	4.09	4.56	4.24
IV	2005	4.20	4.40	4.95	4.52
	2006	4.39	4.50	5.23	4.71
	2007	4.05	4.21	4.49	4.25
Mean – Średnia		4.21	4.37	4.89	4.49
Mean – Średnia	2005	3.93	4.05	4.36	4,11
	2006	4.18	4.10	4.76	4,34
	2007	3.74	3.80	4.14	3,89
Mean – Średnia		3.95	3.98	4.42	4.11

$LSD_{0.05}$ – $NIR_{0,05}$ for – dla:	
cultivation method – sposobu pielęgnacji	0.25
mixture – mieszanki	0.29
years – lat	0.22
interaction – interakcji:	
cultivation method x mixture – sposób pielęgnacji x mieszanka	0.29
cultivation method x years – sposób pielęgnacji x lata	0.25
mixture x years – mieszanka x lata	0.23

In the present study, the average grain yield of the mixtures on this treatment (IV) amounted to 4.49 t·ha^{-1} and was significantly higher than the yield determined for the two other cultivation methods, which amounted to 4.14 and 4.24 t·ha^{-1}, respectively. A higher yield-forming potential of the oat-barley mixture (C), where the average grain yield (4.42 t·ha^{-1}) was significantly higher than the yield of the other two mixtures, on average by 0.45 t·ha^{-1}, was confirmed. The grain yield of mixtures A and B was similar and amounted to 3.95 and 3.98 t·ha^{-1}, respectively. Also in the study by Jakubiak and Gałęzewski [2007] a significantly higher by 0.91 t·ha^{-1} grain yield of an oat-barley mixture was obtained, as compared with the yield of a wheat-barley mixture. However, as opposed to the present study, the difference in yield of the oat-barley mixture as compared with the oat-wheat mixture amounted to 0.16 t·ha^{-1} and was non-significant.

Significant interactions of the years of the study with the experimental factors can prove different response of the mixtures to the weather conditions during the experiment. The lowest grain yield of the mixtures, on average 3.89 t·ha^{-1} was recorded in 2007, which probably resulted from a lower amount of rainfall accompanied by a higher air temperature (Tables 1 and 5). This is confirmed by the study by Rudnicki and Wasilewski [1993], where also a significant effect of rainfall and its distribution throughout the growing period on the grain yield of cereal mixtures was indicated. More favorable meteorological conditions in 2005-2006 resulted in higher yields of the mixtures. Especially significantly higher average yield of mixtures (4.34 t·ha^{-1}) was obtained in 2006 as compared with 2007 (Table 1).

CONCLUSIONS

1. A higher effectiveness in limiting weed infestation was indicated, especially in the oat-barley mixture, the mechanical and chemical method using harrowing and ½ dose of the herbicide Chwastox Trio 540 SL, as compared with postemergence harrowing or the application of the full dose of the herbicide.

2. Applying the herbicide Chwastox Trio 540 SL at the full dose or using harrowing with the half a dose of this preparation showed a similar effectiveness in controlling the dominating species – *Thlaspi arvense* and *Chenopodium album,* and slightly lower in controlling *Viola arvensis* and *Capsella bursa-pastoris*.

3. All the applied cultivation methods influenced a significant increase of grain yield of all the mixtures as compared with the control treatment. Lower grain yields were obtained on the treatments with harrowing and with the full herbicide dose as compared with the application of the herbicide at a smaller dose after previous harrowing.

4. A higher yield-forming potential of the oat-barley mixture than wheat-barley and wheat-oat mixtures was confirmed.

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ZACHWASZCZENIE I PLONOWANIE JARYCH MIESZANEK ZBOŻOWYCH W ZALEŻNOŚCI OD SPOSOBU PIELĘGNACJI

Streszczenie. W latach 2005-2007 w Stacji Dydaktyczno-Badawczej Krasne (50°03' N; 22°06' E) koło Rzeszowa, na glebie brunatnej wytworzonej z lessu, kompleksu pszennego dobrego przeprowadzono badania nad wpływem sposobów pielęgnacji na zachwaszczenie

i plonowanie mieszanek dwugatunkowych z 50% udziałem pszenicy jarej, jęczmienia jarego i owsa. Najwyższą skutecznością w ograniczaniu ogólnej liczby i masy chwastów, zwłaszcza w mieszance owsa z jęczmieniem, odznaczała się metoda mechaniczno-chemiczna z zastosowaniem bronowania i ½ dawki herbicydu Chwastox Trio 540 SL. Stosowanie każdego sposobu pielęgnacji wpłynęło na istotną zwyżkę plonu ziarna mieszanek w porównaniu z obiektem kontrolnym. Istotnie niższe plony ziarna uzyskano na obiektach po zastosowaniu bronowania oraz pełnej dawki herbicydu w porównaniu z aplikacją herbicydu w dawce zmniejszonej po wcześniejszym bronowaniu. Wyższym potencjałem plonotwórczym charakteryzowała się mieszanka owsa z jęczmieniem, której plon wyniósł 4,42 $t \cdot ha^{-1}$ i był istotnie wyższy, średnio o 0,45 $t \cdot ha^{-1}$ od plonu pozostałych mieszanek.

Słowa kluczowe: bronowanie, Chwastox Trio, jęczmień, odchwaszczanie, owies, pszenica

Accepted for print – Zaakceptowano do druku: 02.08.2010