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TILLAGE SYSTEMS AND CATCH CROPS AS FACTORS DETERMINING WEED INFESTATION LEVEL IN A SPRING WHEAT CANOPY (*Triticum aestivum* L.) SOWN IN MONOCULTURE

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Abstract. The studies were carried out in the years 2009-2011 on medium heavy mixed rendzina soil. The aim of the study was comparison of the effect of tillage system and different types of catch crops on the weed infestation level in spring wheat canopy sown in monoculture. The experiment included plough tillage and conservation tillage with autumn and spring disking of catch crops. Four methods of plot regeneration were used in a form of various catch crops. With reference to the control without catch crops, effects of undersown red clover and Dutch ryegrass were compared, as well as of stubble crops of lacy phacelia and white mustard on the weed infestation of spring wheat canopy. Based on the conducted research it was indicated that plough tillage compared with conservation tillage decreased a number of dicotyledonous and monocotyledonous weeds, the total number of weeds and their air dry mass in the spring wheat canopy. Under conservation tillage, compared with plough tillage, there was a higher occurrence of *Avena fatua* and *Cirsium arvense*. Greater species diversity in weeds was observed on plots with conservation tillage. A lower number of monocotyledonous weeds was observed on the plot after stubble crop of white mustard, compared with the control plots where no catch crops were sown. Incorporation of both stubble crops and undersown red clover decreased dry weight of weeds in a spring wheat canopy, both compared with the control and with the plot after undersown grass. On plots after undersown red clover and Dutch ryegrass, a higher number of weed species was observed in the spring wheat canopy, compared with the control without catch crops. Conservation tillage promoted obtaining a higher biomass of catch crops than plough tillage. Undersown red clover produced a significantly lower biomass than stubble crops or undersown Dutch ryegrass.

Key words: conservation tillage, plough tillage, spring wheat, stubble crops, undersown catch crops, weed infestation

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INTRODUCTION

Cereal plants constitute 73.3% of the sowing structure in Poland [Rocznik Statystyczny 2012]. On many farms, cereal cultivation after itself has become a fact. As a consequence, this situation leads to deterioration of physical and chemical properties of soil, increasing in years infection with foot and root rot diseases, and to an increase in the weed infestation level. Consequently, it affects quantity and quality of obtained grain yields [Wesołowski and Kwiatkowski 2000, Kwiatkowski 2009].

A tillage system with a decreased frequency and intensity of the applied treatments is defined as conservation tillage [Weber 2002, Dzienia *et al*. 2006]. Zimny [1999] defined conservation tillage as a cultivation method using mulching, aiming at soil protection against degradation and sustaining its productivity. Plough tillage in Poland is being more and more frequently replaced with conservation tillage [Zimny 1999, Dzienia *et al*. 2006]. A similar tendency is also observed in many other countries [Locke *et al*. 2002, Derpsch and Friedrich 2009, Kassam *et al*. 2009]. It was found that conservation tillage increases the content of organic matter in the soil, and thus increases biological activity of the soil [Kraska 2011, Gajda and Przewłoka 2012, Weber 2012]. At the same time it decreases the risk of leaching out elements outside agrocenosis, and reduces water and wind erosion [Dzienia *et al*. 2006, Weber 2010, Gruber *et al*. 2011]. Lack of ploughing, however, may lead to an increase in the weed infestation level in a crop plant canopy [Kraska and Pałys 2006, Jedruszczak *et al*. 2006, Woźniak 2012, Woźniak and Haliniarz 2012].

Plants sown as catch crops increase competitive abilities of the crop plant's canopy against segetal vegetation, and some affect it with the use of compounds of allelopatic character, which consequently may reduce the number and weight of weeds [Locke *et al*. 2002, Haramoto and Gallandt 2005, Kwiecińska *et al*. 2009, Gawęda and Kwiatkowski 2012]. Particular importance of catch crops results from the fact that they are attributed with plot regenerating properties in the cultivation of cereals sown after themselves [Jaskulska and Gałęzewski 2009, Kwiatkowski 2009, 2012].

Incorporating reduced tillage, consisting in replacing plough with other tillage implements, is becoming more and more common on areas sown with cereals. However, it carries the risk of increasing the level of weed infestation in the canopy. Also, for agricultural practice there is a still topical problem of alleviating negative effects of cereal cultivation in monoculture through the use of catch crops. Therefore, a hypothesis was taken that the use of catch crops under diversified tillage systems may be an effective treatment decreasing weed infestation in spring wheat canopy cultivated after itself. In order to verify these assumptions, studies were carried out whose aim was comparison of the effect of various catch crops under plough tillage and with two variants of conservation tillage, on weed infestation of spring wheat canopy sown in monoculture.

MATERIAL AND METHODS

The studies were carried out in the years 2009-2011, in spring wheat cultivated from 2005 in monoculture on the Fields of the Experimental Farm Bezek (51°19' N; 23°25' E) belonging to the University of Life Sciences in Lublin. The experimental field was located on a medium heavy mixed rendzina soil of a granulometric composition of medium-heavy silty loam (according to standard BN-78/9180-11). According to the new classification of the Polish Society of Soil Science it was loam [PTG 2009]. This soil had an alkaline reaction (pH in 1mole of KCl – 7.35), high content of P – 117.8 and K – 242.4, and a very low content of magnesium – 19.0 (mg·kg^{-1} of soil), while the organic carbon content was 24.7 g·kg^{-1}.

A two-factorial experiment was set up with a split-plot design in four replicates. As the first factor the experimental design included tillage systems: A – plough system and two methods of conservation tillage: B – with autumn and C – spring disking of catch crops. The second experimental factor were methods of regenerating spring wheat plot through incorporation of stubble crops and undersown catch crops. Compared with the control plot without catch crops (a) the effect of undersown catch crops was studied (red clover – b, Dutch ryegrass – c) and stubble crops (lacy phacelia – d, white mustard – e) on the level of weed infestation of the spring wheat canopy. Red clover cv. Dajana – 20 kg·ha^{-1} and multiflorous Dutch ryegrass cv. Mowester – 20 kg·ha^{-1} were sown at the time of sowing spring wheat. However, lacy phacelia cv. Stala – 20 kg·ha^{-1} and white mustard cv. Borowska 20 kg·ha^{-1} were sown after harvesting spring wheat and after conducting post-harvest cultivating measures in mid August. The area for harvest was 30 m^2.

In the plough system, preparing the soil for spring wheat began with skimming and harrowing the field after harvesting the forecrop. In this tillage system, ploughing was carried out to an average depth before winter, both on plots with catch crops and on the control plot. Harrowing was conducted in spring, while cultivating with harrowing before sowing. In spring before sowing wheat the following elements were applied: 60 kg N·ha^{-1}, 30.5 kg P·ha^{-1} and 74.7 kg K·ha^{-1}. The second nitrogen dose of 40 kg N·ha^{-1} was applied at the beginning of shooting (30-33 BBCH). Dressed grain (Panoctine 350 SL) of spring wheat cv. Tybalt was sown at a rate of 5 million grains per ha.

On the plot with conservation tillage (B and C), where the stubble crop were lacy phacelia and white mustard, grubbing was carried out to a depth of 18-20 cm after harvesting spring wheat, as well as harrowing. Next, lacy phacelia was sown and white mustard analogically as in the variant with plough tillage. On plot B, catch crops were disked before winter, and on plot C they were left for winter and disking was carried out in spring. In the variant with autumn disking of catch crops (B), spring tillage was the same as the plough tillage system. In the variant with conservation tillage (C) after disking the field in spring, it was harrowed, and next harrowing was repeated before sowing spring wheat.

In the growing season, protection program for spring wheat canopy included reduction of weed infestation (Chwastox Extra 300 SL at a dose of 3.5 dm^3·ha^{-1} – a.s. 300 g·dm^{-3} MCPA) at the stage 23-29 BBCH, as well as protective treatment against fungal infections (Alert 375 SC 1 dm^3·ha^{-1} – a.s. 125 g·dm^{-3} flusilazole and 250 g·dm^{-3} carbendazim) at the stage 26-29 BBCH.

Evaluation of weed infestation of spring wheat was determined with a quantitative-gravimetric method at the dough stage (stage 85-87 BBCH). Analysis consisted in determining the number and species composition of weeds and their air dry mass on sample plots appointed with a frame of the dimensions of 1 m × 0.25 m on four randomly selected locations of each plot. The air dry mass of catch crops was determined in late October on an area of 0.5 m^2 on each plot in two replicates. Obtained results were elaborated statistically with a method of the analysis of variance. The means were compared with the use of the least significant differences based on Tukey test ($P \leq 0.05$). Calculations were carried out with the use of the statistical program

ARSTAT developed in the Faculty of Applied Mathematics and Information Technology of the University of Life Sciences in Lublin.

Weather conditions

The studied period from April to October in the years 2009-2011 differed with the intensification and distribution of rainfall (Table 1). The total rainfall in the mentioned above period in the years 2009-2010 was higher than the mean from the long-term period for 1974-2010. In the studied period, the mean air temperatures in all years of research were higher than the long-term mean (Table 1). In order to get a more complete analysis of weather conditions, Sielianinow hydrothermal index was calculated according to Radomski [1987]: $K = P/0.1\sum t$, where: P – total monthly rainfall [mm]; $\sum t$ – the total of mean daily air temperatures for the particular month [^{o}C]. Values of the hydrothermal index indicate that in April 2009 and in October 2011, there occurred a significant water deficiency. Also in July, August and September 2009 deficiency in plant supplementation with water was observed. A similar situation occurred in April and October 2010, as well as in May and August 2011 (Table 1).

Table 1. Rainfall, air temperatures and the plants' water resources defined by Sielianinov hydrothermal coefficient (K) in the months April – October in the growing season in 2009-2011, as compared to the long-term mean figures (1974-2010) according to the Meteorological Station at Bezek

Tabela 1. Opady, temperatura powietrza oraz zabezpieczenie roślin w wodę wyrażone współczynnikiem hydrotermicznym Sielianinowa (K) od kwietnia do października sezonu wegetacyjnego 2009-2011 w zestawieniu ze średnimi wieloletnimi (1974-2010) wg Stacji Meteorologicznej w Bezku

Rok Year	Month – Miesiąc							Total Suma
	April kwiecień	May maj	June czerwiec	July lipiec	August sierpień	September wrzesień	October październik	
	Rainfall – Opady, mm							
2009	10.1	86.8	180.5	50.8	46.9	28.8	92.1	496.0
2010	20.4	72.4	94.4	156.0	141.9	93.1	14.3	562.5
2011	30.6	40.8	88.5	178.9	38.5	1.6	27.3	406.2
Means for 1974-2010 Średnie z lat 1974-2010	37.9	57.4	76.9	81.6	69.8	57.1	40.8	421.5
	Rainfall – Opady, mm							Mean Średnia
2009	11.2	13.0	16.2	19.9	18.1	14.9	6.8	14.3
2010	9.0	14.5	17.6	20.8	19.7	11.7	4.8	14.0
2011	9.9	14.2	18.2	18.8	18.4	15.0	7.3	14.5
Means for 1974-2010 Średnie z lat 1974-2010	7.8	13.5	16.3	18.2	17.6	12.9	7.7	13.4
Sielianinov hydrothermal coefficient (K) – Współczynnik hydrotermiczny Sielianinowa (K)								Mean Średnia
2009	**0.30	2.15	3.72	*0.83	*0.83	*0.65	4.35	1.83
2010	*0.76	1.61	1.79	2.42	2.33	2.64	*0.97	1.79
2011	1.03	*0.93	1.62	3.07	*0.67	**0.04	1.20	1.22
Means for 1974-2010 Średnie z lat 1974-2010	1.62	1.37	1.57	1.45	1.28	1.48	1.71	1.50

*K < 1.0 – dry spell – posucha
**K < 0.5 – drought – susza

RESULTS

The number of mono- and dicotyledonous weeds and their total number, as well as the air dry mass determined on plots with plough tillage (A) were significantly lower than under conditions of conservation tillage (B and C). At the same time, mentioned parameters determined under conditions of conservation tillage with autumn disking of catch crops (B) were significantly lower, compared with conservation tillage where catch crops were disked in spring (C) (Tables 2-5). Sowing stubble crops of white mustard in the studied three-year period resulted in a significant decrease in the number of monocotyledonous weeds compared with the control (Table 3). Both the number of dicotyledonous weeds and their total number were not significantly diversified by the sown catch crops (Tables 2-4). However, incorporation of stubble crops of white mustard and lacy phacelia and undersown catch crops of red clover significantly decreased the dry weight of weeds in spring wheat canopy, compared with a plot after undersown grass or with control (Table 5).

Table 2. Number of dicotyledonous weeds in a spring wheat canopy, plant·m^{-2}
Tabela 2. Liczba chwastów dwuliściennych w łanie pszenicy jarej, szt.·m^{-2}

Experimental factor Czynnik doświadczenia		Tillage system – System uprawy			Mean Średnia
		*A	B	C	
Catch crops Międzyplon	control obiekt kontrolny	4.3	9.3	9.3	7.6
	red clover koniczyna czerwona	6.1	7.4	12.1	8.5
	Dutch ryegrass życica westerwoldzka	5.3	9.0	15.8	10.0
	lacy phacelia facelia błękitna	5.2	7.8	10.7	7.9
	white mustard gorczyca biała	4.1	5.9	9.9	6.6
Year Rok	2009	5.7	7.2	8.7	7.2
	2010	6.0	5.0	8.5	6.5
	2011	3.3	11.5	17.5	10.7
Mean – Średnia		5.0	7.9	11.6	–

$LSD_{0.05}$ – $NIR_{0,05}$
tillage systems – systemy uprawy 2.40
years – lata 2.40
interaction – interakcja:
tillage systems × years – systemy uprawy × lata 5.51

*A – plough tillage – uprawa płużna
B – conservation tillage with autumn catch crops disking – uprawa konserwująca z jesiennym talerzowaniem międzyplonów
C – conservation tillage with spring catch crops disking – uprawa konserwująca z wiosennym talerzowaniem międzyplonów

Table 3. Number of monocotyledonous weeds in a spring wheat canopy, plant·m^{-2}
Tabela 3. Liczba chwastów jednoliściennych w łanie pszenicy jarej, szt.·m^{-2}

Experimental factor Czynnik doświadczenia		Tillage system – System uprawy			Mean Średnia
		*A	B	C	
Catch crops Międzyplon	control obiekt kontrolny	33.4	53.0	84.8	57.1
	red clover koniczyna czerwona	23.3	50.2	73.2	48.9
	Dutch ryegrass życica westerwoldzka	24.5	48.1	75.7	49.4
	lacy phacelia facelia błękitna	23.4	54.3	74.8	50.9
	white mustard gorczyca biała	23.4	46.8	69.2	46.5
Year Rok	2009	24.9	28.1	30.7	27.9
	2010	30.0	42.8	86.7	53.2
	2011	22.0	80.6	109.2	70.6
Mean – Średnia		25.6	50.5	75.5	–

$LSD_{0.05}$ – $NIR_{0,05}$
tillage systems – systemy uprawy 5.92
catch crops – międzyplony 8.92
years – lata 5.92
interaction – interakcja:
tillage systems × years – systemy uprawy × lata 13.61

* for explanations, see Table 2 – objaśnienia pod tabelą 2

Table 4. The total number of weeds in a spring wheat canopy, plant·m^{-2}
Tabela 4. Liczba chwastów ogółem w łanie pszenicy jarej, szt.·m^{-2}

Experimental factor Czynnik doświadczenia		Tillage system – System uprawy			Mean Średnia
		*A	B	C	
Catch crops Międzyplon	control obiekt kontrolny	37.8	62.3	94.1	64.7
	red clover koniczyna czerwona	29.4	57.6	85.3	57.4
	Dutch ryegrass życica westerwoldzka	29.8	57.1	91.4	59.4
	lacy phacelia facelia błękitna	28.6	62.1	85.5	58.7
	white mustard gorczyca biała	27.5	52.8	79.1	53.1
Year Rok	2009	30.6	35.3	39.4	35.1
	2010	36.0	47.8	95.2	59.7
	2011	25.3	92.1	126.7	81.3
Mean – Średnia		30.6	58.4	87.1	–

$LSD_{0.05}$ – $NIR_{0,05}$
tillage systems – systemy uprawy 6.88
years – lata 6.88
interaction – interakcja:
tillage systems × years – systemy uprawy × lata 15.79

* for explanations, see Table 2 – objaśnienia pod tabelą 2

Table 5. Dry weight of weeds in a spring wheat canopy, $g \cdot m^{-2}$
Tabela 5. Sucha masa chwastów w łanie pszenicy jarej, $g \cdot m^{-2}$

Experimental factor Czynnik doświadczenia		Tillage system – System uprawy *A	B	C	Mean Średnia
Catch crops Międzyplon	control obiekt kontrolny	140.6	245.2	348.9	244.9
	red clover koniczyna czerwona	96.4	145.6	279.3	173.8
	Dutch ryegrass życica westerwoldzka	125.6	220.6	323.4	223.2
	lacy phacelia facelia błękitna	90.4	171.4	280.8	180.9
	white mustard gorczyca biała	101.2	180.9	253.2	178.4
Year Rok	2009	95.2	138.2	123.5	119.0
	2010	163.1	298.4	445.6	302.4
	2011	74.2	141.6	322.2	179.3
Mean – Średnia		110.8	192.7	297.1	–

$LSD_{0.05}$ – $NIR_{0,05}$	
tillage systems – systemy uprawy	26.26
catch crops – międzyplony	39.53
years – lata	26.26
interaction – interakcja:	
tillage systems × years – systemy uprawy × lata	60.31

* for explanations, see Table 2 – objaśnienia pod tabelą 2

The lowest number of monocotyledonous weeds and weeds in total was observed in 2009, a significantly higher in 2010, while the highest in 2011, which was the last year of observation (Tables 3, 4). The number of dicotyledonous weeds in the last year of studies was higher by 48.6% to 64.6% than in the two first years of observation (Table 2). There was a different situation with reference to the air dry mass of weeds. The lowest air dry mass of weeds in spring wheat canopy was observed in 2009, a significantly higher (by 50.7%) in 2011, and the highest in 2010 (Table 5). This unequivocally indicates the fact that the number of weeds does not always correspond with their air dry mass.

In 2011 in a spring wheat canopy, the lowest number of mono- and dicotyledonous weeds, the total number of weeds and their air dry mass was determined on plots with plough tillage, a significantly higher with conservation tillage with autumn disking of catch crops, and the highest in the variant with conservation tillage where catch crops were disked in spring (Tables 2-5). Moreover, in 2010 the highest number of monocotyledonous weeds, the total weed number and their air dry mass was determined on plots with conservation tillage with spring incorporation of catch crops, compared with the second variant of conservation tillage and with plough tillage (Tables 3-5).

The total number of weeds in a spring wheat canopy determined on control plots and on plots with undersown catch crop of Dutch ryegrass was lower in 2009 than in 2010 or 2011. At the same time, in 2011 on plot after stubble crops and undersown catch crop of red clover, a higher total number of weeds was found than in the first two years of observation (Fig. 1). In 2009 all sown catch crops affected the decrease of the dry weight of weeds in a spring wheat canopy compared with 2010 (Fig. 2).

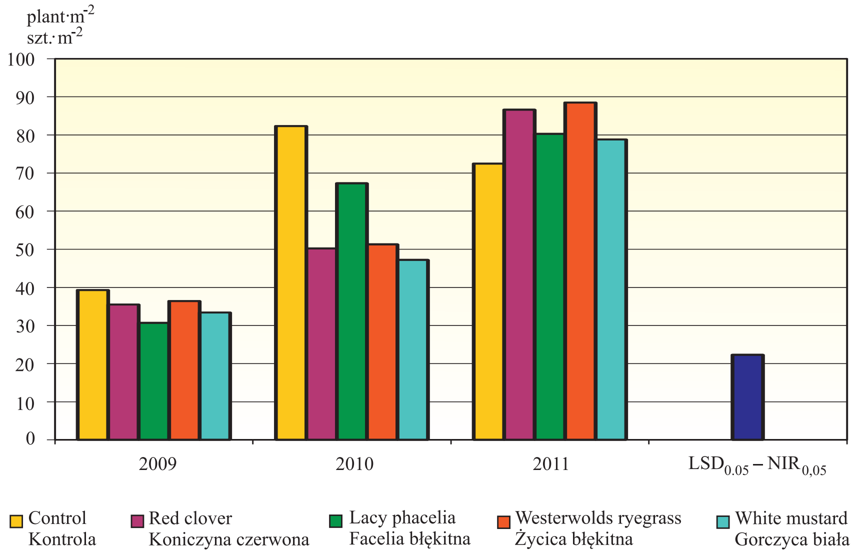

Fig. 1. The total number of weeds in a spring wheat canopy depending on the type of catch crops in the years 2009-2011, plant·m^{-2}

Rys. 1. Liczba chwastów ogółem w łanie pszenicy jarej w zależności od rodzaju międzyplonu w latach 2009-2011, szt.·m^{-2}

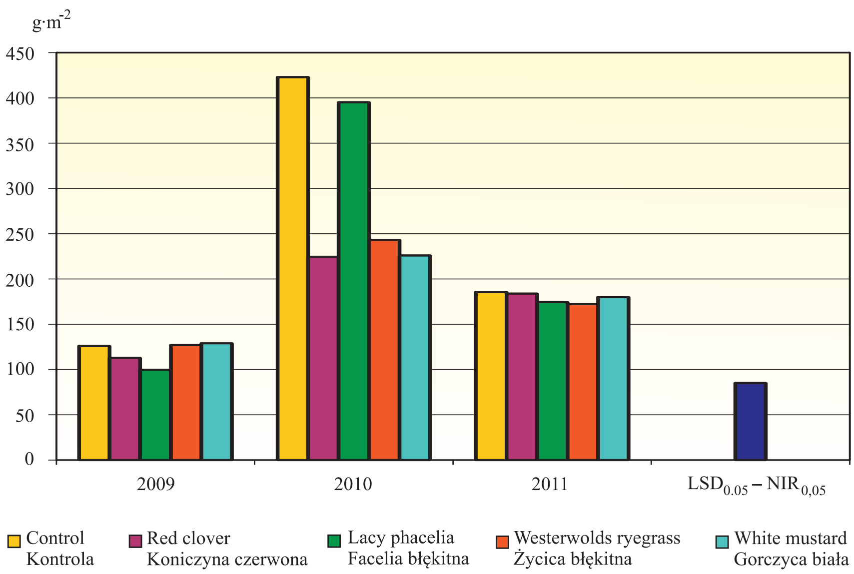

Fig. 2. Dry matter of weeds in a spring wheat canopy depending on the type of catch crops in the years 2009-2011, g·m^{-2}

Rys. 2. Sucha masa chwastów w łanie pszenicy jarej w zależności od rodzaju międzyplonu w latach 2009-2011, g·m^{-2}

In a spring wheat canopy both under conditions of plough tillage and conservation tillage, the prevailing species was *Avena fatua* (Table 6).

Table 6. Species composition and the number of weeds per 1 m^2 of a spring wheat canopy depending on tillage systems (mean figures in the years 2009-2011)
Tabela 6. Skład gatunkowy i liczba chwastów na 1 m^2 w łanie pszenicy jarej w zależności od systemów uprawy roli (średnie z lat 2009-2011)

Weed species – Gatunki chwastów	Tillage system – System uprawy		
	***A	B	C
Dicotyledonous – Dwuliścienne			
1. *Galium aparine* L.	1.6	0.8	1.6
2. **Convolvulus arvensis* L.	1.4	2.0	1.7
3. *Fallopia convolvulus* (L.) Á. Löve	0.6	0.5	1.4
4. *Viola arvensis* Murray	0.5	0.3	0.4
5.**Cirsium arvense* (L.) Scop.	0.2	3.0	3.1
6. *Veronica arvensis* L.	0.2	0.4	0.5
7.**Sonchus arvensis* L.	0.2	0.3	1.5
8. *Stellaria media* (L.) Vill.	0.1	0.2	0.4
9. *Melandrium album* (Mill.) Garcke	0.1	0.0	0.2
10. *Veronica persica* Poir.	0.0	0.2	0.2
11. *Chenopodium album* L.	0.1	—	0.0
12. *Cerastium holosteoides* Fr. Emend. Hyl.	0.0	0.0	0.2
13. *Papaver rhoeas* L.	0.0	0.0	0.0
14. *Medicago lupulina* L.	0.0	0.0	—
15.**Lathyrus tuberosus* L.	—	0.2	—
16.**Taraxacum officinale* F. H. Wigg.	—	0.0	0.2
17. *Matricaria maritima subsp. inodora* (L.) Dostál	—	0.0	0.1
18.**Artemisia vulgaris* L.	—	0.0	0.0
19. **Armoracia rusticana* P. Gaertn., B. Mey. & Scherb.	—	0.0	0.0
20. *Arctium tomentosum* Mill.	—	0.0	0.0
21. *Polygonum aviculare* L.	—	0.0	—
22. *Myosotis arvensis* (L.) Hill	—	—	0.1
23. *Capsella bursa-pastoris* (L.) Medik.	—	—	0.0
24. *Lapsana communis* L. s. str.	—	—	0.0
25. *Lamium amplexicaule* L.	—	—	0.0
Total dicotyledonous – Razem dwuliścienne	5.0	7.9	11.6
Number of dicotyledonous species Liczba gatunków dwuliściennych	14	20	22
**Monocotyledonous – Jednoliścienne			
26. *Avena fatua* L.	25.3	49.1	71.2
27.**Elymus repens* (L.) Gould.	0.1	1.3	3.4
28.**Equisetum arvense* L.	0.1	0.1	—
29. *Setaria viridis* (L.) P. Beauv.	—	0.0	0.2
30. *Setaria pumila* (Poir.) Roem. & Schult.	—	—	0.6
31. *Apera spica-venti* (L.) P. Beauv.	—	—	0.1
32. *Echinochloa crus-galli* (L.) Beauv.	0.1	0.0	–
Total monocotyledonous – Razem jednoliścienne	25.6	50.5	75.5
Number of monocotyledonous species Liczba gatunków jednoliściennych	4	5	5
Total number of weeds – Całkowita liczba chwastów	30.6	58.4	87.1
Number of species – Liczba gatunków	18	25	27

0.0 – species occurring at less than 0.1 plants per m^2 – gatunki występujące w mniej niż 0,1 roślin na m^2
— species not occurring – gatunki niewystępujące
* perennial species of weed – wieloletnie gatunki chwastów; ** with – z *Equisetum arvense* L.
*** A, B, C – for explanations, see Table 2 – objaśnienia pod tabelą 2

On plots with conservation tillage with autumn incorporation of catch crops, the number of this species increased by 94.1%, while under conditions of conservation tillage with spring disking of catch crops their number was over twice as high compared with the plots with plough tillage. The species from the dicotyledonous class which most numerably occurred in the spring wheat canopy both with plough and conservation tillage were *Galium aparine* and *Convolvulus arvensis*. At the same time on plots with conservation tillage there was a more numerable occurrence of a perennial species of *Cirsium arvense*, compared with pough tillage. The highest species diversity of weeds in spring wheat canopy was observed under conditions of conservation tillage with 25 to 27 weed species, while on plots with plough tillage 18 (Table 6).

Incorporation of undersown catch crops of red clover and Dutch ryegrass resulted in an increase in the number of weed species in the spring wheat canopy, compared with the control without catch crops. However, the number of taxa determined on plots after stubble crops was similar or close to the one found on the control plot. In the studied three-year period both on control plots and on the plot after catch crops, the most numerous occurrence was of *Cirsium arvense*, *Convolvulus arvensis* and *Galium aparine* from the dicotyledonous class. From the monocotyledonous class, the most abundant species was *Avena fatua* (Table 7).

Table 7. Species composition and the number of weeds per 1 m^2 of a spring wheat canopy depending on the species of catch crops (mean figures in the years 2009-2011)
Tabela 7. Skład gatunkowy i liczba chwastów na 1 m^2 w łanie pszenicy jarej w zależności od międzyplonów (średnie z lat 2009-2011)

Weed species – Gatunki chwastów	Catch crops – Międzyplony				
	***a	b	c	d	e
1	2	3	4	5	6
Dicotyledonous – Dwuliścienne					
1.**Cirsium arvense* (L.) Scop.	1.9	2.1	2.7	2.0	1.7
2.**Convolvulus arvensis* L.	1.7	1.5	2.1	1.3	1.8
3. *Galium aparine* L.	1.3	1.8	1.3	1.4	0.8
4. *Fallopia convolvulus* (L.) Á. Löve	1.1	0.6	0.9	0.9	0.7
5. *Stellaria media* (L.) Vill.	0.1	0.2	0.2	0.3	0.2
6.**Sonchus arvensis* L.	0.4	0.8	1.3	0.4	0.4
7. *Veronica arvensis* L.	0.3	0.3	0.3	0.3	0.5
8. *Viola arvensis* Murray	0.3	0.2	0.5	0.5	0.2
9. *Veronica persica* Poir.	0.1	0.2	0.1	0.2	0.0
10. *Cerastium holosteoides* Fr. Emend. Hyl.	0.1	0.1	0.1	0.2	0.0
11. *Chenopodium album* L.	0.1	—	0.0	0.0	0.0
12. **Armoracia rusticana* P. Gaertn., B. Mey.& Scherb.	0.1	0.1	—	—	—
13. *Myosotis arvensis* (L.) Hill	0.1	—	—	—	—
14. *Papaver rhoeas* L.	0.0	0.1	0.0	—	—
15. **Artemisia vulgaris* L.	0.0	—	0.0	0.1	—
16. *Melandrium album* (Mill.) Garcke	—	0.2	0.1	0.1	0.1
17.**Taraxacum officinale* F. H. Wigg.	—	0.1	0.1	0.1	0.0
18. *Matricaria maritima subsp. inodora* (L.) Dostál	—	0.1	0.1	—	0.1
19. *Lamium amplexicaule* L.	—	0.1	—	—	—
20.**Lathyrus tuberosus* L.	—	0.0	—	0.1	0.1
21. *Polygonum aviculare* L.	—	0.0	—	—	—
22. *Medicago lupulina* L.	—	—	0.1	0.0	—
23. *Capsella bursa-pastoris* (L.) Medik.	—	—	—	0.0	0.0
24. *Arctium tomentosum* Mill.	—	—	0.1	—	—
25. *Lapsana communis* L. s. str.	—	—	0.0	—	—
Total dicotyledonous – Razem dwuliścienne	7.6	8.5	10.0	7.9	6.6
Number of dicotyledonous species Liczba gatunków dwuliściennych	15	18	19	17	16

Table 7 continued
cd tabeli 7

1	2	3	4	5	6
**Monocotyledonous – Jednoliścienne					
26. *Avena fatua* L.	55.0	45.3	47.2	49.9	45.2
27.**Elymus repens* (L.) Gould	1.7	2.9	1.6	0.8	1.0
28.**Equisetum arvense* L.	0.2	0.1	0.0	—	0.0
29. *Setaria viridis* (L.) P. Beauv.	0.1	0.1	—	0.1	0.1
30. *Setaria pumila* (Poir.) Roem. & Schult.	0.1	0.4	0.4	0.1	0.1
31. *Apera spica-venti* (L.) P. Beauv.	0.0	0.0	0.1	—	0.1
32. *Echinochloa crus-galli* (L.) Beauv.	—	0.1	0.1	—	—
Total monocotyledonous – Razem jednoliścienne	57.1	48.9	49.4	50.9	46.5
Number of monocotyledonous species Liczba gatunków jednoliściennych	6	7	6	4	6
Total number of weeds – Całkowita liczba chwastów	64.7	57.4	59.4	58.7	53.1
Number of species – Liczba gatunków	21	25	25	21	22

0.0 – species occurring at less than 0.1 plants per m^2 – gatunki występujące w mniej niż 0,1 roślin na m^2
— species not occurring – gatunki niewystępujące
* perennial species of weed – wieloletnie gatunki chwastów; ** with – z *Equisetum arvense* L.
*** a – control without catch crops – kontrola bez międzyplonów; b – undersown red clover – wsiewka międzyplonowa koniczyny czerwonej; c – undersown Dutch ryegrass – wsiewka międzyplonowa życicy westerwoldzkiej; d – stubble crop of lacy phacelia – międzyplon ścierniskowy – facelia błękitna; e – stubble crop of white mustard – międzyplon ścierniskowy – gorczyca biała

The air dry mass of catch crops obtained from plots with plough tillage was significantly lower (from 22.9% to 39.7%) than from conservation tillage (Table 8). At the same time, conservation tillage with spring disking of catch crops was favorable for obtaining a higher biomass of catch crops (by 27.9%) than conservation tillage where catch crops were disked in autumn. Red clover in the studied three-year period produced a significantly lower biomass (from 37.4% to 45.4%) than stubble crops or the undersown Dutch ryegrass. The air dry mass of catch crops produced in 2011 was higher from 39.4% to 58.3% than in the first two years of research (Table 8).

Table 8. Air dry mass of catch crops, $Mg \cdot ha^{-1}$
Tabela 8. Powietrznie sucha masa międzyplonów, $Mg \cdot ha^{-1}$

Catch crops Międzyplony	Tillage System – System uprawy			Rok – Year			Mean Średnia
	*A	B	C	2009	2010	2011	
Red clover Koniczyna czerwona	2.25	3.18	4.70	3.63	20.1	4.49	3.38
Dutch ryegrass Życica westerwoldzka	4.51	5.47	6.21	5.32	3.63	7.24	5.40
Lacy phacelia Facelia błękitna	4.90	5.23	7.47	5.10	5.56	6.94	5.87
White mustard Gorczyca biała	4.16	6.58	7.83	5.04	5.59	7.94	6.19
Mean – Średnia	3.95	5.12	6.55	4.77	4.20	6.65	–
$LSD_{0.05}$ – $NIR_{0,05}$							
tillage systems – systemy uprawy	1.011						
catch crops – międzyplony	1.286						
years – lata	1.011						

* for explanations, see Table 2 – objaśnienia pod tabelą 2

DISCUSSION

Kraska and Pałys [2006], Woźniak and Haliniarz [2012] as well as Kraska [2012], while using reduced tillage found an increase in the number and the air dry mass of weeds in a canopy of different cereal species. Małecka and Blecharczyk [2008], however found that no-tillage compared with plough tillage decreased the number of weeds in the spring barley canopy, but it did not reduce the fresh weight of weeds. At the same time Malicki *et al*. [1997], Tørresen *et al*. [2003] as well as Morris *et al*. [2010] found that reduced tillage is favorable for the occurrence of monocotyledonous weeds. Shrestha et al. [2002] observed that level of weed infestation under conditions of incorporating reduced tillage depends on the crop species. It was confirmed in the presented studies. The number of monocotyledonous weeds determined in a spring wheat canopy on plots with no-tillage was from 97.3% to over twice as high as the one found with plough tillage.

In the spring wheat canopy sown under conditions of conservation tillage, a higher species diversity of weeds was proved than in spring wheat cultivated in the plough tillage system, which is confirmed by results obtained by Frant and Bujak [2006], Woźniak and Haliniarz [2012] as well as Kraska [2012]. It is worth noting that in the studied three-year period, level of weed infestation in a spring wheat canopy by common wild oats especially under conditions of conservation tillage, exceeded the critical density level, which according to Kapeluszny [1987] for short-statured wheat and the poorly tillering one is 10-25 panicles of common wild oat per 1 m^2. While incorporating reduced tillage, Ozpinar [2006] also obtained an increase in the number of *Avena fatua* in the winter wheat canopy. On the same soil in the years 2006-2008 under conditions of no-tillage, Kraska [2012] determined a significantly higher number of weed species (34-35), however, the number of *Avena fatua* was significantly lower than in the presented research results. Frant and Bujak [2006], while incorporating reduced tillage in autumn tillage under spring wheat, observed an increase in the number of weeds, and above all of *Apera spica-venti* and *Elymus repens.* In the studies of Wesołowski and Bujak [2006], it was found that incorporating plough tillage increases weed infestation with *Chenopodium album* and *Apera spica-venti*. Therefore, methods of reducing weed infestation in this tillage system are being searched for.

Wanic *et al*. [2004] think that undersown catch crops as a result of direct competitive effect along with a cover crop, may affect inhibition of weed development in a canopy. On the other hand, Oleszek *et al*. [1994] as well as Blackshaw *et al*. [2001] found that catch crops may reduce weed infestation of a crop canopy, while catch crops from the *Brassicaceae* family inhibit seed germination and initial growth of many weed species. Małecka *et al*. [2003] as well as Małecka and Blecharczyk [2008], proved that mulching plants in the form of white mustard and lacy phacelia reduce weed number in the spring barley canopy compared with the combination without mulch, which was confirmed in the authors' research.

In the conducted research, on the plot after undersown catch crop of Dutch ryegrass, the air dry mass of weeds decreased, however this decrease was lower than on plots with other catch crops, despite the fact that the weed number in the wheat canopy was similar to the one on plots after undersown red clover and stubble crop of lacy phacelia. Woźniak [2005], however, found that the ploughed under Dutch ryegrass increased weed infestation of spring wheat. Kuraszkiewicz and Pałys [2003] as well as Kwiecińska-

-Poppe *et al*. [2009] proved that undersown catch crops of Italian ryegrass, red clover and white clover reduced the number and biomass of weeds in a spring barley canopy.

Species diversity of weeds in the spring wheat canopy sown after undersown catch crops was higher than on plots after stubble crops or on the control plot without catch crops. On the other hand, Gawęda and Kwiatkowski [2012], while sowing spring wheat after stubble crops obtained a decrease in the weed number with a simultaneous increase in species diversity, compared with the plot without catch crops. Kraska [2012] however, found the highest species diversity of weeds in the spring wheat canopy sown on control plots than after stubble crops and undersown catch crops. Duer [1994], Andrzejewska [1999], Jaskulski *et al*. [2000], Pawłowski and Woźniak [2000] as well as Kwiatkowski [2009] think that the degree to which catch crops affect regulation of weed infestation is diversified and depends on habitat conditions, cereal species, type of catch crop and plant selection, as well as method of its management.

Quantity of the produced air dry mass of the studied catch crop plants was dependent on the applied tillage system. Conservation tillage, compared with plough tillage, was favorable for obtaining a higher biomass of catch crops. At the same time, the highest air dry mass of catch crops was determined on plots with conservation tillage where catch crops were disked in spring. This might have resulted from a better supplementation with water on plots with conservation tillage compared with plough tillage. Zimny [1999] as well as Weber [2002, 2010] found that a higher moisture of the top soil layer is observed with no-tillage compared to plough tillage. In the studies of Małecka *et al*. [2004], lacy phacelia reacted negatively to reduced tillage. In the authors' research, however, it was found that under conditions of conservation tillage, lacy phacelia produced from 6.3% to 34.4% higher biomass than on the plot after plough tillage.

In the studied three-year period, undersown red clover produced the lowest dry weight, while the stubble crop of white mustard produced the lowest one. However, the air dry mass of weeds determined in the spring wheat canopy sown after red clover as well as after white mustard was similar. According to Duer [1994] and Malicki and Michałowski [1994], successful catch crop sowing producing a large amount of biomass may effectively reduce the number and weight of weeds.

Malicki and Michałowski [1994] think that the condition necessary for a successful stubble crop cultivation is rainfall exceeding 140 mm in the growing season. Also rainfall in the month preceding sowing catch crops is significant. That is probably why a high yield of the dry weight of stubble crops was obtained in 2011 with high rainfall in July (178.9 mm). On the other hand, low yield of undersown catch crops, especially of red clover in the years 2009 and 2010 may have resulted from lack of rainfall in the month of sowing seeds. At that time there occurred drought and a dry spell. Under conditions of favorable rainfall distribution in the years 2010 and 2011 in the period of sowing stubble crops, the biomass produced by white mustard and lacy phacelia was higher or similar to the one produced by undersown catch crops. On the same soil in the years 2006-2008, Kraska [2012] found that with regard to the yield, more reliable were undersown catch crops, compared with stubble crops. Duer [1996] indicates that factors determining success of catch crop cultivation, except water supplementation and proper temperature, is length of the growing season. Zając and Antonkiewicz [2006] state that success of catch crop cultivation may also be determined by the selection of plant species sown as catch crops.

CONCLUSION

1. The use of conservation tillage in the spring wheat canopy, compared with plough tillage, increased the number of dicotyledonous and monocotyledonous weeds, the total weed number and the air dry mass of weeds. Moreover, conservation tillage was favorable for the occurrence of a greater number of weed species, including the perennial ones.

2. The air dry mass of weeds determined in a spring wheat canopy sown after stubble crops of white mustard and lacy phacelia as well as after undersown red clover, was lower, compared with the plot after undersown grass and with the control without catch crops. At the same time, on the plot after undersown catch crops, weed species diversity was higher than after stubble crops.

3. The most abundant species occurring in the spring wheat canopy sown in monoculture were *Avena fatua* and *Cirsium arvense,* and their number increased under conditions of conservation tillage. The air dry mass of catch crops obtained under conditions of conservation tillage was higher than from plough tillage. Stubble crops of white mustard and lacy phacelia as well as undersown Dutch ryegrass, produced a higher biomass than undersown red clover.

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SYSTEMY UPRAWY ROLI ORAZ MIĘDZYPLONY JAKO CZYNNIKI KSZTAŁTUJĄCE POZIOM ZACHWASZCZENIA ŁANU PSZENICY JAREJ (*Triticum aestivum* L.) WYSIEWANEJ W MONOKULTURZE

Streszczenie. Badania przeprowadzono w latach 2009-2011 na średnio ciężkiej rędzinie mieszanej. Celem badań było porównanie wpływu sposobu uprawy roli oraz różnych rodzajów międzyplonów na poziom zachwaszczenia łanu pszenicy jarej wysiewanej w monokulturze. Doświadczenie uwzględniało uprawę płużną oraz konserwującą z jesiennym lub wiosennym talerzowaniem międzyplonów. Zastosowano przy tym cztery sposoby regeneracji stanowiska w postaci różnych międzyplonów. W odniesieniu do kontroli bez międzyplonów porównywano oddziaływanie wsiewek śródplonowych koniczyny czerwonej i życicy westerwoldzkiej oraz międzyplonów ścierniskowych facelii błękitnej i gorczycy białej na zachwaszczenie łanu pszenicy jarej. Na podstawie przeprowadzonych badań wykazano, że płużna uprawa roli w porównaniu z konserwującą zmniejszyła w łanie pszenicy jarej liczbę chwastów dwuliściennych, jednoliściennych, ogólną liczbę chwastów oraz ich powietrznie suchą masę. W warunkach uprawy konserwującej w porównaniu z płużną liczniej wystąpiły *Avena fatua* i *Cirsium arvense*. Większą różnorodność gatunkową chwastów stwierdzono na poletkach, na których zastosowano uprawę konserwującą. W stanowisku po międzyplonie ścierniskowym z gorczycy białej stwierdzono mniejszą liczbę chwastów jednoliściennych w porównaniu z poletkami kontrolnymi, gdzie nie wysiewano żadnych międzyplonów. Wprowadzenie obu międzyplonów ścierniskowych oraz wsiewki z koniczyny czerwonej zmniejszyło suchą masę chwastów w łanie pszenicy jarej zarówno w porównaniu z kontrolą, jak i stanowiskiem po wsiewce trawy. W stanowiskach po wsiewkach śródplonowych z koniczyny czerwonej oraz życicy westerwoldzkiej stwierdzono większą liczbę gatunków chwastów w łanie pszenicy jarej w porównaniu z kontrolą bez międzyplonów. Uprawa konserwująca sprzyjała uzyskaniu większej biomasy międzyplonów niż uprawa płużna. Wsiewka śródplonowa z koniczyny czerwonej wytworzyła istotnie mniejszą biomasę niż międzyplony ścierniskowe i wsiewka z życicy westerwoldzkiej.

Słowa kluczowe: międzyplony ścierniskowe, pszenica jara, uprawa konserwująca, uprawa płużna, wsiewki międzyplonowe, zachwaszczenie

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