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# EFFECT OF TILLAGE SYSTEM AND CATCH CROP ON WEED INFESTATION OF SPRING WHEAT STANDS (*Triticum aestivum* L.)

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**Abstract**. The aim of the research was comparison of the effect of tillage system (ploughing or conservation) and various catch crops and air dry matter produced by them on the level of weed infestation of spring wheat canopy cultivated after itself. The research was carried out in the years 2006-2008 on medium heavy mixed rendzina soil. The static two-factorial experiment included ploughing tillage (A) and conservation tillage with autumn disking of catch crops (B) or with their spring disking (C). At the same time, four methods of stand regeneration were applied in spring wheat monoculture in the form of various catch crops. With reference to the control plot without catch crops (a), effect of undersown catch crops of red clover (b) was compared with westerwold ryegrass (c), as well as stubble catch crops of lacy phacelia (d) and white mustard (e) on the level of weed infestation of spring wheat canopy. Conservation tillage increased species diversity of weeds in the canopy of spring wheat, their total number and air dry mass compared with the ploughing tillage. Introduction of catch crops in the spring wheat monoculture decreased species diversity in segetal flora compared with the control plot (without catch crops). Undersown catch crops of red clover and westerwold ryegrass produced a greater biomass in the evaluated 3-year period, and reduced the number of weeds to a greater extent than stubble catch crops of lacy phacelia and white mustard. Air dry mass of weeds in spring wheat cultivated after undersown catch crop of red clover was significantly lower than after undersown catch crop of westerwold ryegrass. The species that occurred in greatest numbers in the spring wheat canopy were: *Galium aparine*, *Fallopia convolvulus* and *Avena fatua.* Tillage system had no significant effect on the yield of dry matter of catch crop plants. Undersown catch crops reacted to changeable weather conditions to a lesser degree than stubble catch crops.

**Key words**: catch crop, conservation tillage, monoculture, mulch, ploughing tillage, spring wheat

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**INTRODUCTION**

Tillage of decreased frequency and intensity of the applied treatments is defined as conservation tillage [Weber 2002, Dzienia *et al*. 2006]. Zimny [1999] defines conservation tillage as a tillage method with the use of mulching, aiming at the protection of soil against degradation, and preserving its productivity.

Conservation tillage with the use of mulching, compared with ploughing tillage decreases labour-consumption and energy costs in the process of production. This system favourably affects the condition of soil environment [McLaughlin and Mineau 1995, Dzienia *et al*. 2006, Weber 2010]. At the same time, it also reduces water erosion, temperature variations and increases content of organic substance in the soil [Akemo *et al*. 2000, Holland 2004, Kraska 2011]. However, it may lead to the increase in weed infestation and in the number of weed seeds in the soil [Malicki et al. 1997, Kraska and Pałys 2004, Jedruszczak *et al*. 2006, Pullaro *et al*. 2006]. For conservation tillage, cultivators with hard shanks are used as well as rotary harrows, disk harrows, various tilling and sowing units as well as seed drills for direct seeding [Zimny 1999].

Cereal cultivation in monoculture leads to accumulation of many unfavourable phenomena, it promotes, among others, the increase in the weed infestation level [Wesołowski and Kwiatkowski 2000]. Introduction of regenerating plants in the form of winter and stubble catch crops as well as undersown catch crops may effectively reduce negative effects of cereal cultivation in monoculture [Kuraszkiewicz 2004]. Plants cultivated as catch crops increase the competing ability of a crop plant canopy against weeds, and some of them affect them with the use of compounds of allelopathic character, which as a result effectively decreases the number and biomass of weeds [Hauggaard-Nielsen *et al*. 2001, Hochol *et al*. 2004, Haramoto and Gallandt 2005]. Catch crops reduce weed infestation of the crop plant canopy, while those belonging to *Brassicaceae* family inhibit seed germination and initial growth of many weed species [Oleszek *et al*. 1994, Blackshaw *et al*. 2001]. They play the role of plants regenerating the stand, and a phytosanitary role [Wojciechowski 1998, Pawłowski and Woźniak 2000, Holland 2004]. Catch crops should be treated as a component of agrotechnology increasing richness of soil, protecting it against erosion as well as a factor regenerating the cereal crop rotation. Catch crop's effect depends on its type and selection of plant species [Andrzejewska 1999]. According to Wanic *et al*. [2005] undersown catch crops may have a more beneficial effect on the stand than stubble catch crops, this results from a longer period of an undersown catch crop staying on the field, and because of combined counteraction against weed development with cereal plant.

Application of reduced-tillage systems in cereal production in Poland is becoming more and more common. However, it bears the risk of increasing the weed infestation level of the canopy. At the same time, the problem of mitigating negative effects of cereal cultivation in monoculture is also present in the agricultural practice. A hypothesis was made that the use of catch crops in various tillage systems may be an effective treatment decreasing weed infestation in spring wheat canopy cultivated after itself. To verify these assumptions, the research was carried out, whose aim was comparison of tillage systems (ploughing tillage and two conservation tillage systems) as well as various types of catch crops and air dry mass produced by them on the level of weed infestation of spring wheat canopy cultivated in monoculture.

## MATERIAL AND METHODS

The research was carried out in the years 2006-2008, with the use of the experiment set up in 2005 on the Experimental Farm in Bezek (51°19' N; 23°25' E) owned by the University of Life Sciences in Lublin. The experimental field was situated on a medium heavy mixed rendzina soil, formed in cretaceous age of granulometric composition of medium silty clay (granulometric group according to standard BN-78/9180-11). According to the new classification of the Polish Society of Soil Science [2009] it was clay. This soil had an alkaline reaction (pH in 1 mole KCl – 7.35), high content of P – 117.8 and K – 242.4 and very low content of magnesium – 19.0 ($mg \cdot kg^{-1}$ of soil), content of organic carbon 24.7 $g \cdot kg^{-1}$.

The statistical two-factorial field experiment was set up with the use of split-plot design in four replications. As the first factor, the experimental scheme included tillage systems: A – ploughing system as well as two conservation tillage methods: B – with the autumn and C – spring disking of catch crops. The second research factor were methods of stand regeneration in monoculture of spring wheat in the form of various catch crops. On the background of the control plot without catch crops (a) the effect of undersown catch crops (b – red clover, c – westerwold ryegrass) as well as stubble catch crops (d – lacy phacelia, e – white mustard) was compared on the level of weed infestation of spring wheat canopy. Red clover cultivar Dajana – 20 $kg \cdot ha^{-1}$ and westerwold ryegrass cultivar Mowester – 20 $kg \cdot ha^{-1}$ were sown at the time of sowing spring wheat. However, lacy phacelia cultivar Stala – 20 $kg \cdot ha^{-1}$ and white mustard cultivar Borowska 20 $kg \cdot ha^{-1}$ were sown after harvesting spring wheat and after conducting post-harvest tillage measures in the second decade of August. Plot area for harvest was 30 $m^2$. The forecrop was winter wheat cultivated on this field for 3 years. In 2005 spring wheat was sown as well as all catch crops, both the undersown catch crops and stubble catch crops, and tillage systems were applied according to the assumptions of methodology, treating this year as preliminary.

The ploughing tillage system under spring wheat was initiated with skimming and harrowing the field after forecrop harvest. In this tillage system, ploughing was conducted to the medium depth before winter both on the plots with catch crops and on the control plot. In spring, harrowing was conducted, as well as cultivating with harrowing before seeding. Nitrogenous fertilizers at a rate of 60 kg $N \cdot ha^{-1}$ in the form of ammonium saltpeter, phosphorous fertilizers at a rate of 30.5 kg $P \cdot ha^{-1}$ in the form of triple superphosphate and potassium fertilizers at a rate of 74.7 kg $K \cdot ha^{-1}$ in the form of 60% potassium salt were sown in spring. The second rate of nitrogen at a rate of 40 kg $N \cdot ha^{-1}$ was applied at the beginning of the stage of shooting (30-33 development stages BBCH). Spring wheat cultivar 'Zebra' was sown in the number of 5 million grains per ha. The grain was dressed with preparation Panoctine 350 SL (170 ml + 400 ml $H_2O$ per 100 kg of grain).

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

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

Evaluation of weed infestation of spring wheat was determined with the use of quantitative-gravimetric method at the dough stage (at the stage 85-87 BBCH). Analysis consisted in determining the number and species composition of weeds and their air dry mass on sample areas determined with a frame of dimensions 1 m x 0.25 m in four randomly chosen places on each plot. The air dry mass of catch crops was determined at the end of October on an area of 0.5 $m^2$ on each plot in two replications. Obtained results were elaborated statistically with the method of analysis of variance. Mean values were compared with the use of the least significant differences based on Tukey's test ($P \leq 0.05$). Calculations were carried out with the use of statistical program ARSTAT, developed in the Faculty of Applied Mathematics and Information Technology of the University of Life Sciences in Lublin.

### Meteorological conditions

Vegetation periods 2006-2008 differed with intensity and distribution of rainfall. Rainfall total from April to October in 2006 was lower than the mean rainfall total from the long-term period, despite very heavy rainfall in August. Very low rainfall in 2006 was observed in July and September. In the years 2007-2008 in the discussed period the rainfall total was higher than the mean for the long-term period. Particularly high rainfall occurred in the first decade of July in 2007. In May in the years 2007-2008, rainfall total visibly exceeded the mean from the long-term period, while in 2006 it oscillated around the mean from the long-term period. In June only in 2007, the rainfall was similar to the mean in the long-term period, while in other years of experiment lower rainfall was observed in this month. Average air temperatures in all years of research were higher than the average temperature in the long-term period for these months (Table 1).

## RESULTS

Level of weed infestation of spring wheat canopy significantly modified the tillage systems. In the ploughing tillage, the total number of weeds and their air dry mass were significantly lower compared with the conservation tillage (Table 2). Differences between variants of the conservation tillage with reference to the total number of weeds as well as their air dry mass oscillated around the statistical error. The highest number of weeds and their air dry mass was observed in 2007. Whereas in 2007, in all evaluated tillage systems, the number and the air dry mass of weeds were higher than in other years of research (Table 2).

Table 1. Rainfall and air temperature from April to October 2006-2008 as compared to the long-term mean figures (1974-2003), according to the Meteorological Station in Bezek
Tabela 1. Opady i temperatura powietrza od kwietnia do października 2006-2008 w zestawieniu ze średnimi wieloletnimi (1974-2003) według Stacji Meteorologicznej w Bezku

| Year – decade<br>Rok – dekada | | Month – Miesiąc<br>April<br>kwiecień | May<br>maj | June<br>czerwiec | July<br>lipiec | August<br>sierpień | September<br>wrzesień | October<br>październik | Total<br>Suma |
|---|---|---|---|---|---|---|---|---|---|
| | | Rainfall – Opady, mm | | | | | | | |
| 2006 | I | 10.6 | 5.8 | 16.3 | 0.0 | 110.3 | 6.6 | 9.2 | 158.8 |
| | II | 9.0 | 8.0 | 1.7 | 22.6 | 82.6 | 0.0 | 1.9 | 125.8 |
| | III | 5.5 | 42.9 | 5.2 | 3.6 | 48.0 | 0.0 | 11.8 | 117.0 |
| Total – Suma | | 25.1 | 56.7 | 23.2 | 26.2 | 240.9 | 6.6 | 22.9 | 401.6 |
| 2007 | I | 6.3 | 11.5 | 57.7 | 103.3 | 25.6 | 74.9 | 6.8 | 286.1 |
| | II | 5.3 | 31.8 | 23.2 | 20.4 | 46.4 | 5.0 | 11.8 | 143.9 |
| | III | 1.3 | 50.3 | 6.6 | 7.0 | 7.9 | 11.1 | 4.2 | 88.4 |
| Total – Suma | | 12.9 | 93.6 | 87.5 | 130.7 | 79.9 | 91.0 | 22.8 | 518.4 |
| 2008 | I | 12.0 | 36.7 | 0.0 | 39.4 | 10.8 | 14.7 | 35.1 | 148.7 |
| | II | 31.4 | 30.9 | 36.8 | 16.2 | 12.2 | 54.5 | 15.1 | 197.1 |
| | III | 4.5 | 6.6 | 1.6 | 38.3 | 37.9 | 30.3 | 10.1 | 129.3 |
| Total Suma | | 47.9 | 74.2 | 38.4 | 93.9 | 60.9 | 99.5 | 60.3 | 475.1 |
| Mean – Średnia 1974-2003 | | 40.1 | 53.0 | 77.6 | 80.3 | 61.6 | 58.5 | 41.2 | 412.3 |
| | | Temperature – Temperatura, $^oC$ | | | | | | | Mean<br>Średnia |
| 2006 | I | 6.5 | 13.1 | 11.4 | 21.7 | 19.3 | 15.4 | 13.4 | 14.4 |
| | II | 7.7 | 14.5 | 17.8 | 20.5 | 19.3 | 8.3 | 7.7 | 13.6 |
| | III | 12.4 | 13.0 | 20.9 | 22.9 | 15.9 | 14.4 | 9.7 | 15.6 |
| Mean – Średnia | | 8.9 | 13.5 | 16.7 | 21.7 | 18.1 | 12.7 | 10.2 | 14.5 |
| 2007 | I | 5.8 | 9.9 | 18.6 | 17.5 | 18.3 | 13.7 | 10.3 | 13.4 |
| | II | 9.1 | 15.5 | 20.1 | 21.4 | 19.5 | 12.1 | 6.3 | 14.9 |
| | III | 10.2 | 19.9 | 17.2 | 19.4 | 18.9 | 13.9 | 7.2 | 15.2 |
| Mean – Średnia | | 8.3 | 15.3 | 18.6 | 19.4 | 18.9 | 13.2 | 7.9 | 14.5 |
| 2008 | I | 7.9 | 11.7 | 17.8 | 17.3 | 19.8 | 19.3 | 10.6 | 14.9 |
| | II | 8.9 | 13.3 | 16.4 | 18.9 | 21.0 | 8.2 | 10.4 | 13.8 |
| | III | 10.5 | 13.2 | 18.0 | 18.7 | 17.2 | 9.8 | 8.5 | 13.7 |
| Mean – Średnia | | 9.1 | 12.7 | 17.4 | 18.3 | 19.3 | 12.4 | 9.8 | 14.1 |
| Mean – Średnia 1974-2003 | | 7.6 | 13.6 | 16.2 | 17.9 | 17.5 | 12.9 | 7.8 | 13.4 |

The number of dicotyledonous weeds in the variant with ploughing tillage was significantly lower than with conservation tillage, where the catch crops were disked before winter (Table 3). However, the number of monocotyledonous weeds and short-lived weeds in the ploughing tillage was significantly lower compared with the conservation tillage B and C. In the conservation tillage with autumn disking of catch crops, the number of monocotyledonous weeds and short-lived weeds in spring wheat was lower compared with conservation tillage where catch crops were left over for winter as mulch (Table 3). However, the number of perennial weeds observed in the ploughing tillage and conservation tillage with spring incorporation of catch crops was significantly lower than in the variant with conservation tillage with autumn disking of catch crops (Table 3).

Table 2. Number of weeds per 1 $m^2$ and the air-dry matter of weeds in a canopy of spring wheat depending on tillage and years of study, $g \cdot m^{-2}$
Tabela 2. Liczba chwastów na 1 $m^2$ oraz powietrznie sucha masa chwastów w łanie pszenicy jarej w zależności od systemów uprawy roli oraz lat badań, $g \cdot m^2$

| Year – Rok | Tillage system – System uprawy* | | | Mean Średnia |
|---|---|---|---|---|
| | A | B | C | |
| Total number of weeds – Ogólna liczba chwastów | | | | |
| 2006 | 15.4 | 15.4 | 16.3 | 15.7 |
| 2007 | 27.1 | 38.1 | 43.9 | 36.3 |
| 2008 | 11.2 | 24.5 | 29.9 | 21.8 |
| Mean | 17.9 | 26.0 | 30.0 | – |
| $LSD_{0.05}$ – $NIR_{0,05}$ for – dla: | | | | |
| tillage systems – systemów uprawy | | 4.21 | | |
| years – lat | | 4.21 | | |
| interaction – interakcji: | | | | |
| tillage systems x years – systemy uprawy x lata | | 9.67 | | |
| Air-dry matter of weeds – Powietrznie sucha masa chwastów | | | | |
| 2006 | 23.6 | 26.2 | 21.3 | 23.7 |
| 2007 | 96.0 | 199.0 | 168.5 | 154.5 |
| 2008 | 24.2 | 54.8 | 63.3 | 47.5 |
| Mean | 47.9 | 93.3 | 84.4 | – |
| $LSD_{0.05}$ – $NIR_{0,05}$ for – dla: | | | | |
| tillage systems – systemów uprawy | | 24.12 | | |
| years – lat | | 24.12 | | |
| interaction – interakcji: | | | | |
| tillage systems x years – systemy uprawy x lata | | 55.41 | | |

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

Table 3. Number of weeds before harvest in a canopy of spring wheat per 1 $m^2$ depending on tillage systems (mean figures in the years 2006-2008)
Tabela 3. Liczba chwastów przed zbiorem w łanie pszenicy jarej (1 $m^2$) w zależności od systemów uprawy roli (średnie z lat 2006-2008)

| Specification – Wyszczególnienie | Tillage system – System uprawy | | | $LSD_{0.05}$ – $NIR_{0,05}$ |
|---|---|---|---|---|
| | *A | B | C | |
| Number of dicotyledonous weeds<br>Liczba chwastów dwuliściennych | 11.4 | 13.7 | 13.2 | 2.20 |
| Number of monocotyledonous weeds<br>Liczba chwastów jednoliściennych | 6.5 | 12.3 | 16.8 | 3.00 |
| Number of short-lived weeds<br>Liczba chwastów krótkotrwałych | 14.9 | 21.3 | 26.9 | 3.65 |
| Number of perennial weeds<br>Liczba chwastów wieloletnich | 3.0 | 4.7 | 3.1 | 1.57 |

* explanations under Table 2 – objaśnienia pod tabelą 2

The air dry mass of weeds in spring wheat cultivated after undersown catch crop of westerwold ryegrass was significantly higher than after undersown catch crop of red clover. However, the total number of weeds in combination with undersown catch crop of grass was significantly lower than on control plot without catch crops (Table 4). The number of dicotyledonous weeds in spring wheat after undersown catch crop of red clover and westerwold ryegrass was significantly lower than after stubble catch crops of lacy phacelia and white mustard and on control plot (without catch crops) (Table 4). Studied catch crops did not vary significantly the number of monocotyledonous weeds and perennial weeds. The number of short-lived weeds in the spring wheat canopy cultivated after undersown catch crop of red clover or westerwold ryegrass was however significantly lower compared with the control plot and after stubble catch crop of lacy phacelia (Table 4).

Table 4. Weed infestation of a spring wheat canopy per 1 $m^2$ depending on catch crops (mean figures in the years 2006-2008)
Tabela 4. Poziom zachwaszczenia łanu pszenicy jarej na 1 $m^2$ w zależności od międzyplonów (średnie z lat 2006-2008)

| Specification – Wyszczególnienie | Catch crops – Międzyplony* | | | | | $LSD_{0.05}$ $NIR_{0,05}$ |
|---|---|---|---|---|---|---|
| | a | b | c | d | e | |
| Number of dicotyledonous weeds<br>Liczba chwastów dwuliściennych | 14.5 | 9.7 | 10.9 | 14.3 | 14.6 | 3.31 |
| Number of monocotyledonous weeds<br>Liczba chwastów jednoliściennych | 13.4 | 11.6 | 9.9 | 12.2 | 12.0 | ns – ni** |
| Number of short-lived weeds<br>Liczba chwastów krótkotrwałych | 23.8 | 17.5 | 17.8 | 23.6 | 22.4 | 5.49 |
| Number of perennial weeds<br>Liczba chwastów wieloletnich | 4.1 | 3.8 | 3.0 | 2.9 | 4.2 | ns – ni** |
| Total number of weeds<br>Całkowita liczba chwastów | 27.9 | 21.3 | 20.8 | 26.5 | 26.6 | 6.33 |
| Air dry matter of weeds, $g \cdot m^{-2}$<br>Powietrznie sucha masa chwastów, $g \cdot m^{-2}$ | 78.0 | 54.2 | 95.9 | 73.2 | 74.8 | 36.31 |

* a – control without catch crops – kontrola bez międzyplonów, b – undersown red clover – wsiewka międzyplonowa koniczyny czerwonej, c – undersown Westerwolds ryegrass – wsiewka międzyplonowa życicy westerwoldzkiej, d – lacy phacelia stubble crop – międzyplon ścierniskowy facelii błękitnej, e – white mustard stubble crop – międzyplon ścierniskowy gorczycy białej
** ns – ni – non-significant difference – różnica nieistotna

In spring wheat canopy cultivated under conditions of conservation tillage, a higher number of weed species was observed, including perennial weeds, than in spring wheat cultivated in the ploughing tillage system. The number of monocotyledonous taxa both in the ploughing tillage and conservation tillage, was similar, though the species composition was slightly diversified (Table 5). Dicotyledonous weed species that occurred in greatest numbers in spring wheat stands, independently of the tillage system, were *Galium aparine* and *Fallopia convolvulus,* while from the monocotyledonous class – *Avena fatua.* Considering weed species with regard to biological groups, the most frequently occurring one from perennial taxa was *Elymus repens* (Table 5).

The greatest diversity of weed species occurred in spring wheat cultivated on control plot where 34 taxa were found, including 27 which belonged to the dicotyledonous plants class. From the analysis of weed community, with regard to biological groups, it follows that 25 species belonged to short-lived taxa. In wheat cultivated after undersown catch crop or stubble catch crop, slightly lower number of weed species was observed along with their density (Table 6).

Table 5. 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 2006-2008)
Tabela 5. Skład gatunkowy i liczba chwastów na 1 $m^2$ w łanie pszenicy jarej w zależności od systemów uprawy roli (średnie z lat 2006-2008)

| Species – Gatunek | Tillage system – System uprawy | | |
|---|---|---|---|
| | A*** | B | C |
| Dicotyledonous – gatunki | | | |
| *Galium aparine* L. | 3.8 | 4.9 | 4.7 |
| *Fallopia convolvulus* (L.) Á. Löve | 3.6 | 3.3 | 3.1 |
| *Convolvulus arvensis* L.* | 1.6 | 0.7 | 0.6 |
| *Stellaria media* (L.) Vill. | 1.1 | 1.3 | 1.1 |
| *Viola arvensis* Murray | 0.4 | 0.9 | 0.7 |
| *Chenopodium album* L. | 0.2 | 0.1 | 0.2 |
| *Amaranthus retroflexus* L. | 0.2 | 0.1 | 0.7 |
| *Papaver rhoeas* L. | 0.1 | 0.1 | 0.1 |
| *Sonchus arvensis* L.* | 0.1 | 0.3 | 0.1 |
| *Veronica arvensis* L. | 0.1 | 0.3 | 0.3 |
| *Melandrium album* (Mill.) Garcke | 0.1 | 0.1 | 0.4 |
| *Polygonum lapathifolium* L. *subsp. lapathifolium* | 0.1 | 0.2 | 0.2 |
| *Cirsium arvense* (L.) Scop.* | 0.0 | 0.3 | 0.1 |
| *Veronica persica* Poir. | 0.0 | 0.1 | 0.1 |
| *Medicago lupulina* L. | 0.0 | 0.1 | 0.0 |
| *Anagallis arvensis* L. | 0.0 | 0.1 | – |
| *Matricaria maritima subsp. inodora* (L.) Dostál | 0.0 | 0.0 | 0.3 |
| *Consolida regalis* Gray | 0.0 | 0.0 | 0.0 |
| Other dicotyledonous – Pozostałe dwuliścienne | – | 0.8 | 0.5 |
| Dicotyledonous in total– Suma dwuliściennych | 11.4 | 13.7 | 13.2 |
| Number of dicotyledonous species<br>Liczba gatunków dwuliściennych | 19 | 29 | 28 |
| Monocotyledonous – Jednoliścienne** | | | |
| *Avena fatua* L. | 3.9 | 7.3 | 6.8 |
| *Elymus repens* (L.) Gould.* | 1.2 | 2.7 | 2.2 |
| *Setaria viridis* (L.) P. Beauv. | 1.1 | 1.1 | 2.2 |
| *Setaria pumila* (Poir.) Roem. & Schult. | 0.2 | 0.5 | 1.3 |
| *Equisetum arvense* L.* | 0.1 | 0.3 | – |
| *Apera spica-venti* (L.) P. Beauv. | 0.0 | 0.4 | 4.3 |
| *Echinochloa crus-galli* (L.) Beauv. | – | – | 0.0 |
| Monocotyledonous in total – Suma jednoliściennych | 6.5 | 12.3 | 16.8 |
| Number of monocotyledonous species<br>Liczba gatunków jednoliściennych | 6 | 6 | 6 |
| Number of short-lived weeds<br>Liczba chwastów krótkotrwałych | 14.9 | 21.3 | 26.9 |
| Number of perennial weeds – Liczba chwastów wieloletnich | 3.0 | 4.7 | 3.1 |
| Number of short-lived species – Gatunki krótkotrwałe | 20 | 27 | 25 |
| Number of perennial species – Gatunki wieloletnie | 5 | 8 | 9 |
| Total number of weeds – Całkowita liczba chwastów | 17.9 | 26.0 | 30.0 |
| Number of species – Liczba gatunków | 25 | 35 | 34 |

0.0 – below 0.1 weeds per 1 $m^2$ – poniżej 0,1 szt. na 1 $m^2$
– species not occurring – gatunek nie występował
* perennial species of weeds – gatunki wieloletnie
** with *Equisetum arvense* L. – z *Equisetum arvense* L.
*** explanations under Table 2 – objaśnienia pod tabelą 2

Table 6. Species composition and the number of weeds per 1 $m^2$ of a spring wheat canopy depending on species of catch crops (mean figures in the years 2006-2008)
Tabela 6. Skład gatunkowy i liczba chwastów na 1 $m^2$ w łanie pszenicy jarej w zależności od międzyplonów (średnie z lat 2006-2008)

| Species – Gatunek | Catch crops – Międzyplony | | | | |
|---|---|---|---|---|---|
| | a*** | b | c | d | e |
| Dicotyledonous – Dwuliścienne | | | | | |
| *Galium aparine* L. | 4.5 | 4.4 | 3.9 | 5.0 | 4.4 |
| *Fallopia convolvulus* (L.) Á. Löve | 3.9 | 2.3 | 3.0 | 3.6 | 3.9 |
| *Stellaria media* (L.) Vill. | 1.4 | 0.6 | 0.8 | 1.3 | 1.5 |
| *Convolvulus arvensis* L. * | 0.8 | 0.9 | 1.3 | 0.7 | 1.0 |
| *Viola arvensis* Murray | 0.8 | 0.3 | 0.3 | 0.9 | 0.9 |
| *Amaranthus retroflexus* L. | 0.7 | 0.1 | 0.2 | 0.3 | 0.5 |
| *Veronica arvensis* L. | 0.3 | 0.0 | 0.3 | 0.4 | 0.1 |
| *Matricaria maritima subsp. inodora* (L.) Dostál | 0.3 | 0.0 | 0.1 | 0.1 | 0.2 |
| *Solanum nigrum* L. emend. Mill. | 0.2 | – | 0.1 | – | 0.2 |
| *Cirsium arvense* (L.) Scop. * | 0.2 | 0.1 | 0.1 | 0.1 | 0.3 |
| *Sonchus arvensis* L. * | 0.2 | 0.2 | 0.1 | 0.1 | 0.2 |
| *Chenopodium album* L. | 0.2 | 0.2 | 0.2 | 0.3 | 0.2 |
| *Melandrium album* (Mill.) Garcke | 0.2 | 0.2 | 0.1 | 0.2 | 0.3 |
| *Taraxacum officinale* F. H. Wigg. * | 0.2 | 0.1 | 0.1 | 0.1 | 0.2 |
| *Anagallis arvensis* L. | 0.1 | 0.1 | – | 0.1 | 0.1 |
| *Papaver rhoeas* L. | 0.1 | 0.0 | 0.1 | 0.1 | 0.1 |
| *Consolida regalis* Gray | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| *Veronica persica* Poir. | 0.1 | – | 0.0 | 0.1 | 0.0 |
| Other dicotyledonous – Pozostałe dwuliścienne | 0.3 | 0.2 | 0.2 | 0.9 | 0.5 |
| Dicotyledonous in total– Suma dwuliściennych | 14.5 | 9.7 | 10.9 | 14.3 | 14.6 |
| Number of dicotyledonous species<br>Liczba gatunków dwuliściennych | 27 | 21 | 25 | 24 | 27 |
| Monocotyledonous – Jednoliścienne** | | | | | |
| *Avena fatua* L. | 5.4 | 6.2 | 5.6 | 6.5 | 6.1 |
| *Apera spica-venti* (L.) P. Beauv. | 2.6 | 2.1 | 0.6 | 1.1 | 1.4 |
| *Elymus repens* (L.) Gould* | 2.5 | 2.5 | 1.4 | 1.6 | 2.2 |
| *Setaria viridis* (L.) P. Beauv. | 1.8 | 0.5 | 1.5 | 1.8 | 1.7 |
| *Setaria pumila* (Poir.) Roem. & Schult. | 0.8 | 0.3 | 0.8 | 0.9 | 0.6 |
| *Equisetum arvense* L. * | 0.2 | – | 0.0 | 0.3 | – |
| *Echinochloa crus-galli* (L.) Beauv. | 0.1 | – | – | – | – |
| Monocotyledonous in total – Suma jednoliściennych | 13.4 | 11.6 | 9.9 | 12.2 | 12.0 |
| Number of monocotyledonous species<br>Liczba gatunków jednoliściennych | 7 | 5 | 6 | 6 | 5 |
| Number of short-lived weeds<br>Liczba chwastów krótkotrwałych | 23.8 | 17.5 | 17.8 | 23.6 | 22.4 |
| Number of perennial weeds – Liczba chwastów wieloletnich | 4.1 | 3.8 | 3.0 | 2.9 | 4.2 |
| Number of short-lived species – Gatunki krótkotrwałe | 25 | 20 | 24 | 23 | 24 |
| Number of perennial species – Gatunki wieloletnie | 9 | 6 | 7 | 7 | 8 |
| Total number of weeds – Całkowita liczba chwastów | 27.9 | 21.3 | 20.8 | 26.5 | 26.6 |
| Number of species – Liczba gatunków | 34 | 26 | 31 | 30 | 32 |

0.0 – below 0.1 weeds per 1 $m^2$ – poniżej 0,1 szt. na 1 $m^2$
– species not occurring – gatunek nie występował
* perennial species of weed – gatunki wieloletnie
** with *Equisetum arvense* L. – z *Equisetum arvense* L.
*** explanations under Table 4 – objaśnienia pod tabelą 4

Comparing plots with catch crops, the highest number of species (32) and the highest number of weeds was observed in spring wheat cultivated after white mustard, the lowest number of taxa was determined after undersown catch crop of red clover (26). In spring wheat cultivated after catch crops compared with the control plot, it was found that *Apera spica-venti*, *Elymus repens*, *Fallopia convolvulus* and *Setaria viridis* occurred in slightly lower intensity, while *Avena fatua* in a higher one (Table 6).

Tillage systems did not significantly affect quantity of the produced air dry mass of the studied catch crop plants. There only occurred a visible tendency towards producing their greater mass under conditions of conservation tillage with spring disking of catch crops. Undersown catch crop of red clover produced a significantly greater dry mass than stubble catch crop of white mustard (Table 7).

The air dry mass of the studied catch crops was varied in the years of research. In 2007 with the highest rainfall total, the dry mass of catch crops was the highest and similar to the one produced in 2008. However, in 2006 which was characterized by a high rainfall deficiency in June, July and September, their mass was the lowest. In 2007 and 2008, lacy phacelia and white mustard sown as stubble catch crop produced a significantly higher air dry mass than in 2006. At the same time in 2006, the biomass of stubble catch crops was lower than the one produced by undersown catch crops (Table 7).

Table 7. Air dry mass of catch crops, $Mg \cdot ha^{-1}$
Tabela 7. Powietrznie sucha masa międzyplonów, $Mg \cdot ha^{-1}$

| Catch crops<br>Międzyplony | Tillage System – System Uprawy | | | Year – Rok | | | Mean<br>Średnia |
|---|---|---|---|---|---|---|---|
| | *A | B | C | 2006 | 2007 | 2008 | |
| Red clover<br>Koniczyna czerwona | 3.16 | 3.95 | 3.72 | 3.18 | 4.35 | 3.30 | 3.61 |
| Westerwolds ryegrass<br>Życica westerwoldzka | 2.95 | 3.22 | 3.57 | 2.98 | 3.13 | 3.62 | 3.24 |
| Lacy phacelia<br>Facelia błękitna | 2.93 | 2.44 | 3.58 | 0.91 | 3.92 | 4.13 | 2.98 |
| White mustard<br>Gorczyca biała | 2.84 | 2.13 | 2.82 | 1.17 | 3.77 | 2.85 | 2.60 |
| Mean – Średnia | 2.97 | 2.93 | 3.42 | 2.06 | 3.79 | 3.47 | – |

$LSD_{005}$ – $NIR_{0,05}$ for – dla:
catch crops – międzyplonów 0.739
years – lat 0.584
interaction – interakcji:
catch crops x years – międzyplony x lata 1.639

* explanations under Table 2 – objaśnienia pod tabelą 2

## DISCUSSION

Weed infestation of spring wheat measured with the total number of weeds in ploughing tillage was lower by 31.2% compared with conservation tillage with autumn disking of catch crops, and 40.3% compared with conservation tillage where catch crops were disked in spring. In the ploughing tillage compared with conservation tillage, the air dry mass of weeds decreased from 43.2 to 48.7%. In the research of Duer [1994], leaving catch crop plants in the form of mulch for winter caused increase in weed infestation of spring barley canopy. Although the number of weeds per area unit was lower, their dry mass was higher. In author's research, under conditions of conservation tillage with spring disking of catch crops, the number of weeds was higher by 15.4%, and their dry mass was lower by 9.5% compared with the variant where catch crops were disked in autumn. However, statistical verification of the obtained results did not confirm significance of these differences. In the research of Małecka *et al*. [2003], mulching plants compared with the control plot without mulch reduced the number of weeds in spring barley canopy from 20 to 25%.

The level of weed infestation in spring wheat canopy measured with the total number of weeds and their air dry mass in 2007 was definitely higher than in other years of research. This may have resulted from low temperatures occurring in the initial stage of vegetation, until the first decade of May inclusive, and from the high rainfall in the period from mid-May until the first decade of June. Such weather conditions promoted weed emergence and reduced possibility of effective herbicide application. The number of weeds in spring wheat canopy in 2007 was over twice as high compared with the first year of research, while compared with 2008 by 66.5%. At the same time, the air dry mass of weeds in that year exceeded several times the obtained one in the years 2006 and 2008.

In the spring wheat canopy, under conditions of conservation tillage, species *Avena fatua* occurred in a slightly higher intensity compared with the ploughing tillage. At the same time, slightly higher number of *Apera spica-venti* was found in wheat canopy under conditions of conservation tillage with spring incorporation of catch crops. It is worth emphasizing that in the evaluated 3-year period, level of weed infestation of the spring wheat canopy by the common wild oat and wind bentgrass did not reach critical concentration, which according to Kapeluszny [1986, 1987] for dwarf wheat and poorely-tillering wheat is 10-25 panicles of common wild oat per 1 $m^2$, while for wind bentgrass 10-25 panicles per 1 $m^2$. Frant and Bujak [2006], while introducing reductions in the autumn tillage under spring wheat consisting in replacing pre-winter ploughing with cultivator tillage, also observed increase in the number of weeds, and above all in *Apera spica-venti* and *Elymus repens.* Kraska and Pałys [2004], also observed an increase in the concentration of *Apera spica-venti* in winter rye canopy in no-till system compared with the ploughing tillage.

Conservation tillage with autumn disking of catch crops caused a slight increase in the number of perennial weeds in the spring wheat canopy, compared with other evaluated tillage systems. This may have resulted from the fact of applying disk harrow in autumn, increasing the risk of weed infestation by *Elymus repens*. Although, the level of weed infestation of spring wheat canopy with this species was low, increase in the number of common couch shoots was observed under conditions of conservation tillage with autumn incorporation of catch crop biomass. Kapeluszny [1988], as critical density of common couch shoots in winter wheat canopy regards 10-50 $stems \cdot m^{-2}$. In the discussed experiment, the number of stems of *Elymus repens* in the canopy of wheat was significantly lower. Niewiadomski and Nowicki [1970] also think that disking may lead to vegetative reproduction of common couch. Similarly, Dzienia *et al*. [2003] proved that long-term application of reduction in tillage increases the number and mass of perennial weeds compared with annual ones. Zanin *et al*. [1997] found that reductions in tillage, compared with ploughing tillage, promote occurrence of annual species. Similarly, in the author's research, the number of short-lived weeds in the spring wheat canopy under conditions of conservation tillage increased significantly compared with the ploughing tillage (from 43.0 to 80.5%).

In the spring wheat canopy, cultivated after undersown catch crops, decrease in the total number of weeds was observed from 23.7 to 25.4% compared with the control plot without catch crops. However, in wheat cultivated after stubble catch crops, the number of weeds decreased to a slight degree (from 4.7 to 5.0%). Obtaining such dependences may have resulted from the direct competitive effect of undersown catch crops along with cover crops on the development of weeds in the canopy [Wanic *et al*. 2004]. It is also worth noting that the biomass produced by undersown catch crops was greater than the one obtained from stubble catch crops. Research of other authors [Teasdale *et al*. 1991, Duer 1994, Oleszek *et al*. 1994, Deryło 1997, Akemo *et al*. 2000, Wanic *et al*. 2005, Gawęda 2009, Kwiatkowski 2009] also indicates the decrease in the number of weeds in stands along with the increase in the quantity of biomass of catch crops which were ploughed or left on the field surface. The obtained results concerning the mass of weeds are slightly different. The air dry mass of weeds in the spring wheat canopy cultivated after stubble catch crops and undersown catch crop of red clover decreased from 4.1 to 30.5% compared with the control plot. Only in spring wheat cultivated after undersown catch crop of ryegrass, the air dry mass of weeds was greater from 22.9 to 76.9%, compared with other evaluated combinations. It results from the fact that undersown catch crop of westerwold ryegrass while reducing the number of weeds in the wheat canopy, did not affect the decrease in its air dry mass. Woźniak [2005] found, however, that ploughed undersown catch crop of westerwold ryegrass increased weed infestation of spring wheat. However, in the research of Wanic *et al*. [2005], predominance of undersown catch crop of Italian ryegrass over red clover in the canopy of spring barley was visible in the reduction of weed biomass. On the other hand, Kuraszkiewicz and Pałys [2003] as well as Kwiecińska-Poppe *et al*. [2009], found that undersown catch crops of Italian ryegrass, red clover and white clover, reduced the number and biomass of weeds in spring barley canopy. Similarly, in the research of Stupnicka-Rodzynkiewicz *et al*. [1988], it was determined that undersown catch crops of Persian clover reduced weed infestation of spring barley and oat, competing directly with weeds. In the research of Gawęda [2009], the lowest weed mass in spring wheat canopy was obtained on plot after catch crop of lacy phacelia, compared with the control plot without catch crops. Differences in research results are caused by the fact that strength of the effect of catch crops on the regulation of weed infestation is varied and depends on the habitat conditions, cereal species, type of catch crop and choice of plants, as well as on the method of its management [Duer 1994, Andrzejewska 1999, Jaskulski *et al*. 2000, Pawłowski and Woźniak 2000, Wanic *et al*. 2005].

In the author's research, stubble catch crop of white mustard, compared with the control plot, did not significantly decrease, either the number or the air dry mass of weeds in the spring wheat canopy. Results obtained by Kwiatkowski [2009], however, indicate that, compared with the control variant (without catch crop), there is a significant decrease in the number and mass of weeds in the spring barley canopy, sown after stubble catch crop of white mustard. Duer [1994] as well as Malicki and Michałowski [1994], state that successful catch crop stands which produce a large amount of biomass, effectively reduce the number and mass of weeds. This particularly concerns the allelopathic effect of cruciferous plant species, which probably while releasing biologically active substances, inhibit germination of weed seedlings. Oleszek *et al*. [1994] as well as Haramoto and Gallandt [2005], confirmed in plants from

*Brassicaceae* family presence of compounds inhibiting germination and then development of other plants.

Introduction of stubble catch crops and undersown catch crops into monoculture of spring wheat, changed the species composition of segetal flora and the percentage of particular species. The lowest number of weed species was observed in spring wheat cultivated after undersown catch crop of red clover. Kuraszkiewicz and Pałys [2003] also found that undersown catch crop of red clover reduced the number of weed species in the spring barley canopy the best. Similarly, Wanic *et al*. [2005] as well as Kwiecińska-Poppe *et al*. [2009] observed that weed species diversity in the canopy of barley cultivated after undersown catch crops was lower than in the cultivation of spring barley after itself (without an undersown catch crop). In the research of Kwiatkowski [2009], westerwold ryegrass and white mustard, reduced the number of weed species in spring barley canopy the most.

From the research of Teasdale *et al*. [1991], Akemo *et al*. [2000] as well as Wanic *et al*. [2005] it follows that catch crops reduce or increase the number of predominant species of short-lived weeds, which proves the complexity of the effect of these cultures on weed infestation. In the spring wheat canopy cultivated after stubble catch crops and undersown catch crops, compared with the control variant a tendency was observed towards higher weed infestation of the canopy by *Avena fatua*, while *Apera spica-venti* occurred in a slightly lower concentration.

The biomass of undersown catch crops obtained in both variants of conservation tillage was visibly higher than on plots with ploughing tillage. This may have resulted from higher soil moisture under conditions of conservation tillage. Zimny [1999] and Weber [2002, 2010] state that with the presence of mulch on the field surface with no-till system, higher moisture of the upper soil layers is observed compared with the ploughing tillage. In the research of Małecka *et al*. [2004], plants cultivated with stubble catch crop reacted differently to tillage system. Lacy phacelia reacted negatively to tillage reduction consisting in substituting plough with stubble cultivator, or in the application of direct seeding. On the other hand, in the author's research, in the variant with conservation tillage with spring disking of catch crops, lacy phacelia produced by 22.2% higher biomass than under conditions of ploughing tillage. However, statistical verification of the obtained results did not confirm significance of these differences.

Air dry mass of catch crops determined in 2007 (with the highest rainfall total) was higher from 9.2 to 84.0% compared with other years. The level of water supply, temperature and length of vegetation period are the factors determining the success of catch crop cultivation. [Duer 1996]. Malicki and Michałowski [1994] emphasize that the condition of the success of cultivation of stubble catch crops is rainfall exceeding 140 mm in their vegetation period. At the same time, the rainfall in the month preceding the catch crop seeding is also important. The optimum temperature is from 13 to 14$^{o}$C, and the lower one than 12$^{o}$C had a negative effect. Confirmation of these dependences are low yields of the dry mass of stubble catch crops of white mustard and lacy phacelia obtained in this experiment in 2006, when there occurred a deficiency of rainfall in July, and above all because of low rainfall in September. However, higher yield of the dry mass of both undersown catch crops resulted probably from a longer period of staying on the field and from the possibility of having high for 2006 rainfall in August. At the same time, under conditions of relatively beneficial distribution of rainfall in 2007 and 2008, the biomass produced by stubble catch crops was equal to the one obtained from undersown catch crops or even exceeded it.

## CONCLUSIONS

1. Conservation tillage compared with ploughing tillage affected the increase in the diversity of weed species in the spring wheat canopy, their number and air dry mass.
2. In the spring wheat canopy cultivated after stubble catch crops and undersown catch crops, lower species diversity was observed compared with the cultivation of spring wheat on the stand without catch crops.
3. Undersown catch crops of red clover and westerwold ryegrass produced a higher biomass and to a greater extent reduced weed number in the spring wheat canopy than stubble catch crops of lacy phacelia and white mustard.
4. The most frequently occurring species in the spring wheat canopy cultivated in monoculture were *Galium aparine*, *Fallopia convolvulus, Elymus repens* and *Avena fatua*.
5. Tillage systems had no significant effect on the quantity of biomass produced by catch crop plants. Undersown catch crops in the evaluated three-year period were less unreliable in yield than stubble catch crops.

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# WPŁYW SYSTEMU UPRAWY ROLI I MIĘDZYPLONU NA ZACHWASZCZENIE ZASIEWÓW PSZENICY JAREJ (*Triticum aestivum* L.)

**Streszczenie**. Celem badań było porównanie wpływu systemu uprawy roli (płużnego i konserwującego) i różnych międzyplonów oraz wytworzonej przez nie powietrznie suchej masy na poziom zachwaszczenia łanu pszenicy jarej uprawianej po sobie. Badania przeprowadzono w latach 2006-2008 na średnio ciężkiej rędzinie mieszanej. Statyczne, dwuczynnikowe doświadczenie uwzględniało uprawę płużną (A) oraz konserwującą z jesiennym talerzowaniem międzyplonów (B) lub wiosennym ich talerzowaniem (C). Zastosowano przy tym cztery sposoby regeneracji stanowiska w monokulturze pszenicy jarej w postaci różnych międzyplonów. W odniesieniu do obiektu kontrolnego bez międzyplonów (a) porównywano oddziaływanie wsiewek śródplonowych koniczyny czerwonej (b) i życicy westerwoldzkiej (c) oraz międzyplonów ścierniskowych facelii błękitnej (d) i gorczycy białej (e) na poziom zachwaszczenia łanu pszenicy jarej. Uprawa konserwująca zwiększała w łanie pszenicy jarej różnorodność gatunkową chwastów, ich ogólną liczbę i powietrznie suchą masę w porównaniu z uprawą płużną. Wprowadzenie międzyplonów w monokulturze pszenicy jarej zmniejszyło różnorodność gatunkową flory segetalnej w stosunku do obiektu kontrolnego (bez międzyplonów). Wsiewki śródplonowe koniczyny czerwonej i życicy westerwoldzkiej wytworzyły większą biomasę w ocenianym trzyleciu i bardziej ograniczyły liczbę chwastów niż międzyplony ścierniskowe facelii błękitnej i gorczycy białej. Powietrznie sucha masa chwastów w pszenicy jarej uprawianej po wsiewce koniczyny czerwonej była istotnie mniejsza niż po wsiewce życicy westerwoldzkiej. Gatunkami najliczniej występującymi w łanie pszenicy jarej były: *Galium aparine*, *Fallopia convolvulus* i *Avena fatua*. System uprawy roli nie oddziaływał istotnie na plon suchej masy roślin międzyplonów. Wsiewki międzyplonowe w mniejszym stopniu reagowały na zmienne warunki pogodowe niż międzyplony ścierniskowe.

**Słowa kluczowe**: międzyplon, monokultura, mulcz, pszenica jara, uprawa konserwująca, uprawa płużna

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