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Effects of Catch Crops and Tillage System on Weed Infestation and Health of Spring Wheat

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ABSTRACT

The paper presents results of research on weed infestation and health of spring wheat grown in the three-year monoculture. The field experiment was carried out on loess soil, classified as "good wheat complex" (soil class II). The first experimental factor was the type of Catch Crop (CC): (a) Object control, no catch crop, (b) White mustard, (c) Tansy phacelia, and (d) Mixture (bean+spring vetch+oat). The second factor was Tillage System (TS): (a) Plow Tillage (PT), and (b) Conservation Tillage (plowless tillage, CT). It was proved that catch crops (especially white mustard) could be an effective way to reduce the negative effects of growing spring wheat in monoculture. This causes both the reduction of the number and weight of weeds in the field, as well as reduction of the proportion of fungal pathogens infecting wheat plants. The regenerating effects of catch crops in the three-year wheat monoculture were more effective under conventional tillage conditions compared to conservation tillage. It also showed that the conservation tillage system had significant effect on increasing the quantitative indicators of weed infestation of wheat and increasing the number of weed seeds in the soil. Conventional tillage with plowing resulted in smaller biodiversity of weed species than conservation tillage system. Tillage method did not cause differentiation degree of infection of wheat stem base by a fungal disease complex. Catch crops, in particular white mustard, proved to be an effective method to reduce the degree of infection of spring wheat by fungal pathogens.

Keywords: Fungal diseases, Catch crops, Conservation tillage, Tillage systems, White mustard.

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INTRODUCTION

Many authors point out increased weed infestation in cereal crops caused by monoculture cropping (Liebman and Dyck, 1993; Gawęda and Kwiatkowski, 2012). In the opinion of Moyer *et al*. (1994), the harmfulness of weeds is determined not by the number of species but by the total number of weeds and total weed weight. As a result of increased weed pressure, the weed seed bank in the soil also increases (Lemerle *et al*., 2001). Weed seed banks are reserves of viable seeds present in the soil. These consist of new seeds recently shed by a weed plant as well as older seeds that have persisted in soil for several years (Shrestha, *et al*., 2002). Besides, a consequence of continuous cereal cropping is also an increased accumulation of a complex of fungal diseases caused by *Gaeumannomyces graminis, Oculimacula yallundae* and *Fusarium* ssp. (Dawson and Bateman, 2000; Solarska, 2007). The pathogens causing these diseases, transferred through the soil and crop residue, damage the roots and vascular bundles of the stem (Akinsanmi *et al*., 2004). Higher infection by root and foot rot diseases as well as an increased dry weight and number of weeds can be particularly seen in the first 2-3 years of a monoculture and it is termed the *'decline effect'* (Cook and Weller, 2004). One of the methods to reduce the negative effects of continuous cropping is to incorporate cover

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crop biomass into the soil (Harasimowicz-Hermann and Hermann, 2006). The effects of cover crop biomass on the soil properties as well as on weed infestation and crop health depend, among others, on the cover crop species and its chemical composition (Wilczewski, 2007; Brant *et al*., 2009). Conventional plow tillage is an energy- and labour-consuming element of agricultural practice (Weber, 2002, Ozpinar and Ozpinar, 2011). However, compared with the plowless tillage it reduces weed infestation of the fields, but destroys the structure of the topsoil and reduces soil biodiversity (Anderson, 2004, Chokor *et al.,* 2008). Conservation tillage combined with the use of mulching reduces labour and energy inputs by 35% in the production process (Weber, 2010). Nevertheless, some authors note that it can lead to increased weed infestation and a higher number of weed seeds in the soil (Pullaro *et al*., 2006). According to Tørresen and Skuterud (2002) plowless tillage increases the supply of diaspores in the upper soil layer where the seeds germinate and increasing weed infestation of the successive crop.

A hypothesis was made in the present study that the regenerative effects of catch crops (reduction in weed infestation of the crop and in foot rot diseases of spring wheat) would be similar under both plowless and plow tillage conditions. Such a situation would allow weeds and fungal pathogens to be effectively reduced from a cereal crop with lower energy inputs (plowing is the most energy-consuming tillage operation). The aim of this study was to determine the degree of weed infestation of a crop and the soil as well as the infection by foot rot diseases in spring wheat grown in a three-year monoculture as influenced by selected catch crops and two tillage systems (plow tillage and conservation tillage).

MATERIALS AND METHODS

Experimental Design

A controlled field experiment on continuous cropping of spring wheat (*Triticum aestivum* L.) was conducted during the period 2010-2012. It was located at the Czesławice Experimental Farm belonging to the University of Life Sciences in Lublin (Poland), on loess soil with the granulometric composition of silt loam (PWsp), classified as good wheat soil complex (soil class II). Prior to the experiment, the soil was characterized by slightly acidic pH–6.5 (examined in 1M KCl), with high or very high availability of phosphorus (170 mg kg^{-1} of soil), potassium (231 mg kg^{-1} of soil) and magnesium (70 mg kg^{-1} of soil), the humus content (1.53%).

The experimental design included two factors: First, species of plant grown as a Catch Crop (CC) in a spring wheat monoculture: (A) Control treatment (without catch crop); (B) White mustard (*Sinapis alba* L.); (C) Tansy phacelia (*Phacelia tanacetifolia* Benth.), and (D) Faba bean (*Vicia faba* ssp. *minor* L.)+spring vetch (*Vicia sativa* L.)+oat (*Avena sativa* L.). Secondly, Tillage System (TS) - after the harvest of catch crops and before the sowing of the cereal crop: (1) Plow Tillage (PT) - after the harvest of catch crops (October), their biomass was shredded and incorporated into the soil during autumn plowing; in the spring, a seedbed cultivator was used, mineral NPK fertilization was applied, and spring wheat was sown with a seed drill. (2) Conservation Tillage (plowless tillage, CT) - after the harvest of catch crops (October), their biomass was left in the field in the form of mulch (until 15 March); in the spring – the mulch was incorporated into the soil using a disk harrow, the field was smoothed with a spike tooth harrow, mineral NPK fertilization was applied, and spring wheat was sown with a seed drill.

The experiment was set up as a split-plot design with 5 replicates, in 27 m^2 plots. Taking into account the initial high soil nutrient availability and cover cropping, the following rates of mineral fertilizers were determined for spring wheat (kg ha^{-1}): N, 60; P_2O_5, 50; K_2O, 70; and for catch crops (kg ha^{-1}): N, 40 (white mustard and tansy phacelia); N, 20 (faba bean+spring

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vetch+oats). Each year, catch crops were sown during the period 14-17 August. The seeding rate was as follows, respectively: White mustard, 20 kg ha^{-1}; tansy phacelia, 5 kg ha^{-1}; faba bean+spring vetch+oats, 80+40+60 kg ha^{-1}. Spring wheat (at a rate of 200 kg ha^{-1}) was sown in the second 10-day period of April. Spring wheat seeds were dressed with the seed dressing Raxil 060 FS (tebuconazol) at a rate of 50 mL per 100 kg of seeds. The other crop protection agents were used in the lower limits of the recommended rates (in line with the "economical" crop protection strategy followed in the experiment) and included: [Herbicide] Sekator 6,25 WG (amidosulfuron+iodosulfuron-methyl-sodium+mefenpyr-diethyl), 0.2 kg ha^{-1} (at tillering stage, BBCH 27-28); [Fungicide] Alert 375 SC (flusilazole+carbendazim), 0.9 l ha^{-1} (at stem elongation, BBCH 31-32); [Growth retardant] Stabilan 750 SL (chlormequat chloride), 0.9 l ha^{-1} (from the 1st node stage until the flag leaf just visible stage, BBCH 31-37). The spring wheat was harvested in the second decade of September.

Observations

Catch crop biomass was determined in the third 10-day period of October. Whole plants were pulled out from an area of 1 m^2 in each plot. After the catch crops were first cut, the remaining biomass left in the plots was plowed under in the autumn (plow tillage) or was left in the form of mulch, until 15 March (conservation tillage). Weed infestation in the spring wheat crop was determined at the flowering stage of wheat (BBCH 65) using the dry-weight-rank method. The number and botanical composition of weeds as well as their air-dry weight were determined in 1×0.5 m^2 sampling areas in two replicates per each plot. The evaluation of weed seed infestation of the soil in the 0-20 cm layer was made after the harvest of spring wheat using the direct method; samples collected in 3 places in each plot by means of cylinders with a 25 cm^2 cross section were washed (in 0.25 mm mesh sieves) and subsequently all the diaspores were counted. Viable weed seeds were separated using 70% potassium carbonate solution.

The infection of spring wheat plants by a complex of pathogens causing foot rot diseases was determined at the milk stage (BBCH 75). Fifty plants were pulled out from each plot. After the soil was washed out, the plants were divided based on the degree of stem base infection into groups in accordance with a 5-point scale: (I) 1-10 % infected stem base; (II) 11-25%; (III) 26-50%; (IV) 51-75%, (V) 76-100%.

Next, the disease index was calculated for foot rot diseases following McKinney's Formula (Lacicowa, 1969):

$$\text{Disease index} = \frac{\sum_a}{\sum_b} 100$$

Where: $\sum_a$ is the sum of numerical values of the scale multiplied by the number of plants corresponding to a particular value; $\sum_b$ is the total number of plants examined multiplied by the highest value of the scale.

Statistical Analyses

The results were statistically analyzed and verified by Tukey's test at a significance level of $P< 0.05$. The statistical analysis was presented using Statgraphics 5.0 software.

Weather Conditions at the Study Site

The growing seasons in the period 2010-2012 varied in rainfall intensity and distribution as well as in temperature compared to the corresponding long-term means (Figures 1 and 2). The first season was warm and wet, in particular during the spring and summer growth period. Based on a comparison with an average rainfall of

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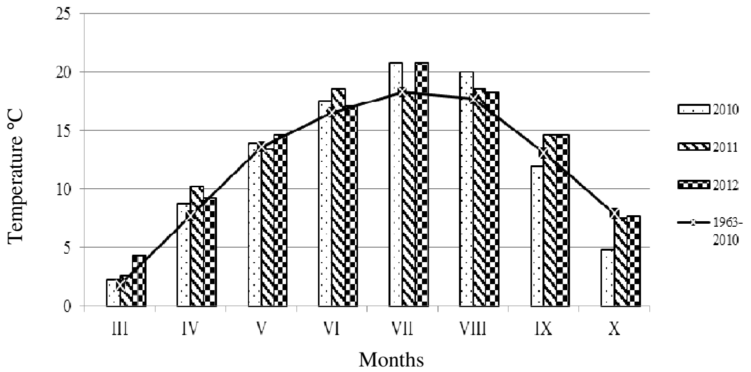

Figure 1. Mean monthly air temperature (°C) at the Czesławice Meteorological Station in 2010-2012.

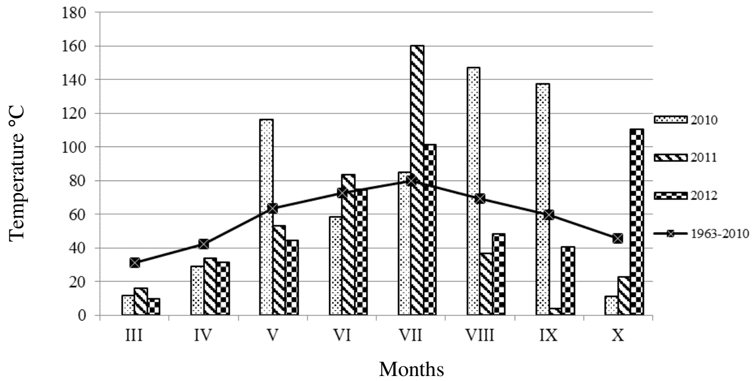

Figure 2. Total rainfall and rainfall distribution (mm) at the Czesławice Meteorological Station in 2010-2012.

multi-year, the second and third years of the study were dry and very warm.

RESULTS

Biomass of Catch Crops

Among the analyzed catch crops, mustard and phacelia had the highest biomass productivity, regardless of the tillage system (Table 1). A similarly high air-dry weight (only 2.7% lower than mustard) was obtained from tansy phacelia catch crops. The legume-cereal mixture proved to be the most unreliable catch crop. Its biomass was 40% lower than that of the other species, which had a clear effect on increasing the weight and number of weeds in treatment D.

Number and Weight of Weeds

Weed infestation in the spring wheat crop, as expressed by weed air-dry weight per unit area, was significantly dependent on both experimental factors. On average, for the study period, catch cropping had a clear effect on reducing the air-dry weight of weeds in the spring wheat crop relative to the control treatment (Table 2). The white mustard cover crop caused the highest reduction in weed air-dry weight (more than 4 times), followed by tansy phacelia (a 3-fold reduction) and the legume-cereal mixture (a nearly 2-fold reduction). It should be noted that the cultivation of white mustard and tansy phacelia resulted in

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Table 1. Air-dry weight of catch crops (in t ha^{-1}) after the harvest (mean for 2010-2012).

CC [b]	TS [a]		
	PT [c]	CT [d]	Mean
white mustard	4.06	4.01	4.03
tansy phacelia	3.98	3.87	3.92
faba bean + spring vetch + oats	2.48	2.31	2.39
Mean	3.51	3.40	-
LSD $_{0.05}$ TS= NS [e], CC= 0.356, TS×CC= NS			

[a] Tillage System; [b] Catch Crop; [c] Plow Tillage; [d] Conservation Tillage, [e] Not Significant.

Table 2. Air-dry weight of weeds in the spring wheat crop (in g m^{-2}) (mean for 2010-2012).

CC [b]	TS [a]		
	PT [c]	CT [d]	Mean
A – control treatment (without CC)	21.2	48.6	34.9
B – white mustard	4.6	11.2	7.9
C – tansy phacelia	6.7	15.8	11.2
D – faba bean + spring vetch + oats	12.6	25.7	19.1
Mean	11.3	25.3	-
LSD $_{0.05}$ TS= 5.98, CC= 6.34, TS×CC= 19.31			

[a] Tillage System; [b] Catch Crop; [c] Plow Tillage; [d] Conservation Tillage.

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significantly lower weed infestation of the spring wheat crop compared to the plot after the legume-cereal mixture (respectively, 2.4 and 1.7 times).

Significantly the highest dry weight of weeds in the wheat crop was found in the control treatment (without catch crop). Conservation tillage, which consisted in shredding the mulch in the spring and incorporating the cover crop residue into the soil using a seedbed cultivator, resulted in lower weed air-dry weight in treatments B and C than in the plowed plot without cover crop. The above study results allow us to conclude that catch cropping (especially white mustard and tansy phacelia) and conservation tillage significantly reduced weed biomass in the spring wheat crop compared to plow tillage without catch crops. Nevertheless, the use of catch crops under the conventional (plow) tillage system contributed to a more effective reduction (on average by more than two times) in weed dry weight compared to conservation tillage. Regardless of the cover crop, conservation tillage contributed to more than twice higher weed infestation in the crop compared to plow tillage (Table 2).

The data included in Table 3 show that it was in the third year of the monoculture that the air-dry weight of weeds in the spring wheat crop distinctly increased, in particular in the treatments with conservation tillage. In the treatments with particular cover crops,

Table 3. Air-dry weight of weeds in the spring wheat crop in the 2nd–3rd year of the monoculture (2010 - 1st year of the monoculture = 100%), regardless of the catch crop).

Year	Number of years of monoculture	TS [a]		
		PT [b]	CT [c]	Mean
2011	2	108	115	111
2012	3	121	157	139
Mean		114	136	-

[a] Tillage System; [b] Plow Tillage, [a] Conservation Tillage.

Table 4. Species composition and number of weeds per 1 m^2 in the spring wheat crop depending on the catch crop (mean for 2010-2012).

Species	CC [a] A [*]	B	C	D	Mean
I. Annual					
1. *Viola arvensis* Murray	13.4	7.2	10.1	9.7	10.1
2. *Chenopodium album* L.	7.3	4.9	6.0	4.4	5.6
3. *M. maritima* ssp. *inodora* (L.) Dostál	6.5	3.0	8.2	8.0	6.4
4. *Galinsoga parviflora* Cav.	4.2	1.5	5.3	2.1	3.3
5. *Stellaria media* (L.) Vill.	2.2	0.0 [b]	0.0	1.4	0.9
6. *Myosotis arvensis* (L.) Hill	1.9	0.0	0.4	2.0	1.1
7. *Apera spica–venti* (L.) P. Beauv.	1.5	0.1	0.3	4.0	1.5
8. *Echinochloa crus–galli* (L.) P. Beauv.	0.9	0.4	0.8	2.5	1.1
9-30. Other annual species	2.5	1.4	2.3	2.0	2.0
Total annuals	40.4 a [**]	18.5 b	33.4 a	36.1 a	32.0
II. Perennial					
1. *Elymus repens* (L.) Gould	8.7	2.6	7.3	10.4	7.2
2. *Cirsium arvense* (L.) Scop.	2.3	0.5	0.8	0.6	1.0
3-6. Other perennial species	3.3	1.0	0.1	2.9	1.8
Total perennials	14.3 a	4.1 b	8.2 c	13,9 b	10.0
Total number of weeds (I+II)	54.7 a	22.6 b	41.6 c	50.0 a	42.0
Total number of weed species	23	19	20	25	22

[a] Catch Crop; [b] Less than 0.1 plant per 1 m^2. [*] A: Without catch crop, B: White mustard; C: Tansy phacelia; D: Faba bean+spring vetch+oats. [**] Means in the rows followed by different letters (a–c) are significantly different (P< 0.05).

weed air-dry weight was not found to show significant variation between years.

The number of weeds in the spring wheat crop was clearly modified under the influence of cover crops (Table 4). The highest reduction in the total number of weeds was found in the case of the white mustard cover crop, both compared to the control treatment (on average by 59%) and relative to treatments C and D (by 46 and 55%, respectively). The cultivation of tansy phacelia resulted in a 24% reduction in the number of weeds in the wheat crop relative to the control (without catch crop), whereas in the case of the legume-cereal mixture weed infestation was at a level similar to that found in the control treatment, with reduction of weed number by 9%. It is worth noting that the reduction in the number of weeds in the spring wheat crop under the influence of white mustard and tansy phacelia cover crops related to annual and perennial weeds to the same extent. Growing catch crops, except for the legume-cereal mixture, had an effect on lower weed biodiversity in the spring wheat crop (the number of total weed species was lower by 3-4 compared to the control).

Floristic Composition of Weed Species

Among the cover crops in question, white mustard reduced weed infestation to the greatest extent, which was probably attributable to the allelopathic properties (inhibitory in relation to weeds) of crop residue of this plant. White mustard had a limiting effect on the number of weeds, in particular in the case of weed species such as: *Chenopodium album, Viola arvensis, Galinsoga parviflora, Matricaria maritima* ssp. *inodora, Elymus repens,* and *Cirsium arvense.* Tansy phacelia and the legume-cereal mixture showed a similar effect on reducing the number of weeds in the spring wheat crop (Table 4). In addition to the weed-killing effect in relation to most of the weed flora, the above-mentioned cover crops caused an increase in the number of some weed species relative to the control

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treatment: tansy phacelia (*Galinsoga parviflora, Matricaria maritima* ssp. *inodora*), legume-cereal mixture (*Matricaria maritima* ssp. *inodora, Apera spica-venti, Echinochloa crus-galli, Elymus repens*).

The total number of weeds per 1 m^2 in the spring wheat crop in the treatments with conservation tillage was on average higher by 17 plants (48%) compared to plow tillage (Table 5). In considering the relationships between the numbers of weeds in the crop broken down into weed groups (annuals, perennials), we noted that conservation tillage contributed to 67% increase in the density of annual weeds and only 2.0% increase in the number of perennial weeds compared to the conventional tillage system. This shows that conservation tillage promotes stronger development of annual weeds compared to perennial ones. Plow tillage contributed to lower biodiversity of weed species (25 species relative to 28 species found in the conservation tillage system).

Similar weed species dominated under both tillage systems. In most cases, the species of *Stellaria media, Chenopodium album. Matricaria maritima ssp. inodora, Viola arvensis* and *Myosotis arvensis* developed a smaller number of plants under conventional tillage system whereas the species of *Echinochloa crus-galli, Elymus repens* and *Cirsium arvense* provided a significantly higher number of plants under conventional tillage compared to conservation tillage system (Table 5).

Soil Seed Bank of Weeds

In the first year of monoculture of spring wheat, weed seed bank in the soil did not differ significantly between the different treatments of the experiment (Table 6). In this period, only higher trend of seed bank in the control treatment has revealed comparing to the treatments witch catch crops. Significant changes in weed seed bank in the soil occurred only in the third year of monoculture, as illustrated in Table

Table 5. Dominant species composition and number of weeds per 1 m^2 in the spring wheat crop depending on the tillage system (mean for 2010-2012).

Species	CT [a]	PT [b]	Decrease (–) or increase (+) in the number of weeds relative to CT
I. Annual			
1. *Viola arvensis* Murray	11.0	6.8	-4.2
2. *M. maritima* ssp. *inodora* (L.) D.	7.7	5.1	-2.6
3. *Chenopodium album* L.	7.7	3.5	-4.2
4. *Stellaria media* (L.) Vill.	4.1	2.5	-1.6
5. *Galinsoga parviflora* Cav.	4.1	2.5	-1.6
5. *Myosotis arvensis* (L.) Hill	1.4	0.8	-0.6
7. *Apera spica–venti* (L.) P. Beauv.	1.9	1.1	-0.8
8. *Echinochloa crus-galli* (L.) P. Beauv.	0.9	1.3	+0.4
9-30. Other annual species	2.7	1.3	-1.4
Total annuals	41.5 a *	24.9 b	-16.6
II. Perennial			
1. *Elymus repens* (L.) Gould	7.0	7.4	+0.4
2. *Cirsium arvense* (L.) Scop.	0.8	1.2	+0.4
3-6. Other perennial species	2.3	1.3	-1.0
Total perennial	10.1 a	9.9 a	-0.2
Total number of weeds (I+II)	51.6 a	34.8 b	-16.8
Total number of weeds species	28	25	-

[a] Conservation Tillage, [b] Plow Tillage, * Means in the rows followed by different letters (a–b) are significantly different (P= 0.05).

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Table 6. The number of seeds in the soil (pcs per 1 m^2) in soil layer 0-20 cm.

CC [b]	TS [a]	
	PT [c]	CT [d]
A: Control treatment (Without CC)	15764	15884
B: White mustard	15165	15209
C: Tansy phacelia	15219	15334
D: Faba bean+spring vetch+oats	15416	15607
Mean	15391	15509
LSD $_{0.05}$ TS= NS [e], CC= NS, TS×CC= NS		

[a] Tillage System; [b] Catch Crop; [c] Plow Tillage; [d] Conservation Tillage, [e] Not Significant.

Table 7. Changes in the size of the soil weed seed bank in the 3rd year of the spring wheat monoculture (Number of seeds in the 1st year of the monoculture= 100%).

CC [b]	TS [a]		
	PT [c]	CT [d]	Mean
A: Control treatment (Without CC)	23.5	49.6	36.5
B: White mustard	-5.7	12.9	3.6
C: Tansy phacelia	9.4	19.3	14.3
D: Faba bean+spring vetch+oats	16.3	20.8	18.5
Mean	10.9	25.6	-
LSD $_{0.05}$ TS= 13.37, CC= 14.98, TS×CC= 12.78			

[a] Tillage System; [b] Catch Crop; [c] Plow Tillage, [d] Conservation Tillage.

7. Growing spring wheat in the 3rd year of continuous cropping without cover crop contributed to an increase in the soil weed seed bank by 23.5% (plow tillage) and 49.6% (conservation tillage). The cover crops had a significant effect on reducing the weed seed bank relative to the control in both tillage systems (Table 7). It should be noted that in the conventional tillage treatments the white mustard cover crop caused a slight decrease in the seed bank after 3 years of the monoculture. The other cover crops did not compensate for the negative effects of three-year continuous cropping of spring wheat and the increase in the seed bank in these plots was 9–16% (plow tillage) and 13–21% (conservation tillage). Significantly the highest increase in the weed seed bank was found in the conservation tillage treatment without cover crop.

Fungal Diseases

On average for the study period, all catch

Table 8. Infection index of the spring wheat stem base by a fungal disease complex (%) (mean for 2010-2012).

CC [b]	TS [a]		
	PT [c]	CT [d]	Mean
A: Control treatment (Without CC)	29.3	33.4	31.3
B: White mustard	10.5	13.2	11.8
C: Tansy phacelia	14.7	15.9	15.3
D: Faba bean+spring vetch+oats	16.2	18.4	17.3
Mean	17.7	20.2	-
LSD $_{0.05}$ TS=NS [e], CC= 11.32,TS×CC= NS			

[a] Tillage System; [b] Catch Crop; [c] Plow Tillage; [d] Conservation Tillage, [e] Not Significant.

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crops contributed to a statistically proven reduction in the occurrence of fungal pathogens relative to the control treatments. The tillage system did not affect the degree of infection of the spring wheat stem base by a fungal disease complex (Table 8).

The third year of the spring wheat monoculture had an effect on increasing the infection index of the spring wheat stem base by a fungal disease complex, on average by 15% under the control conditions. As a result of cover cropping, in the third year of the monoculture, the mean of stem base infection index was higher only by 1.6–7.7% than in the first year (Table 9). The tillage system did not significantly affect the change in the index of infection by fungal diseases during the study period. But the study found a significant interaction: in the treatments without cover crop, the wheat stem base infection index increased by 20.4% in the third year of continuous cropping relative to the first year. It can be presumed that higher fungal disease index in the third year of monoculture (2012) was also related to the weather conditions, since the mean annual temperatures and the total rainfall were more contributive to higher stem base infection by a fungal disease complex in 2012 than in the favourable 2010 (the first year of monoculture).

DISCUSSION

In the present experiment, catch crops had a statistically significant effect on reducing the air-dry weight and number of weeds in the spring wheat crop. Akemo *et al*. (2000) and Hauggard-Nielsen *et al.* (2001) consider cover crops to be an environmentally friendly method of reducing weed infestation in a crop. Moyer *et al*. (2007) found a clear reduction in weed infestation (in particular in the case of *Chenopodium album* by about 80%) under the influence of cover cropping. Species of the family *Brassicacae,* which contain chemical compounds inhibiting the germination and then development of weeds, are especially recommended (Ngouajio *et al*., 2003; Haramoto and Gallandt, 2005). Cover crops producing a large amount of biomass significantly reduce the number and weight of weeds (Gawęda and Kwiatkowski, 2012). This is corroborated by the results of the present experiment in which successful white mustard crops most effectively contributed to reducing weed infestation in the spring wheat crop especially in comparison with legume-cereal mixture. Based on the example of triticale, Płaza and Ceglarek (2008) as well as Parylak *et al*. (2009) also underline the great role of a white mustard cover crop in reducing weed dry weight (by 55%) and number of weeds (by 59%).

Table 9. Changes in the infection index of the spring wheat stem base by a fungal disease complex in the third year of the spring wheat monoculture (Infection index in the first year of the monoculture= 100%).[a]

CC [b]	TS [a]		
	PT [c]	CT [d]	Mean
A: Control treatment (Without CC)	10.0	20.4	15.2
B: White mustard	0.7	2.6	1.6
C: Tansy phacelia	3.4	7.1	5.2
D: Faba bean+spring vetch+oats	6.2	9.3	7.7
Mean	5.1	9.8	-
LSD $_{0.05}$ TS= NS [e], CC= 8.13, TS×CC= 9.74			

[a] Tillage System; [b] Catch Crop; [c] Plow Tillage; [d] Conservation Tillage, [e] Not Significant.

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In the present study, the legume-cereal mixture proved to be a cover crop that was the least weed competitive. Kwiecińska-Poppe *et al*. (2009) indicate that particular cover crop species have varying effects on weeds.

The conservation tillage system contribution to weed infestation in the spring wheat crop was higher than the plow tillage system. This related in particular to an increase in weed dry weight and the number of annual weeds in the crop. Duer (1994) notes that leaving cover crops in the form of mulch for the winter period increases weed infestation in a wheat crop. Dzienia *et al.* (2006) as well as Stenberg *et al.* (1999) are of the opinion that the use of reduced tillage increases the number and weight of weeds and it also results in an increase in the proportion of perennial weeds, in particular *Elymus repens*. In our experiment, conservation tillage caused a minimal (2%) increase in the percentage of perennial weeds in the spring wheat monoculture, while the percentage of *Elymus repens* in weed infestation was even slightly lower. Such findings are supported by the results of the studies of Kraska and Pałys (2004) as well as of Woźniak and Haliniarz (2012). Studying the cultivation of spring wheat, Woźniak (2011) found a significant increase in weed dry weight under no-till conditions compared to plow tillage. Moreover, he observed the dominance of annual weeds such as: *Chenopodium album, Stellaria media, Avena fatua,* and *Echinochloa-crus-galli.* The above-mentioned species were also predominant in the experiment in question and, additionally, *Viola arvensis, M. maritima* ssp. *inodora,* and *Galinsoga parviflora.* The negative influence of no-tillage on the degree of weed infestation is also confirmed by the results of the studies of Gruber and Claupein (2009), Romaneckas *et al.* (2009) and Knezevic *et al*. (2009). It should be noted that the successive years of the spring wheat monoculture contributed to an increase in the soil weed seed bank, in particular where cover cropping was not used. At the same time, such a situation led to the impoverishment of weed biodiversity, which is in agreement with the views of Sekutowski and Domaradzki (2009) as well as of Mahmood *et al*. (2012).

The tillage system did not have a significant effect on increased infection of the spring wheat stem base by a fungal disease complex. On the other hand, stubble crops played a large role in reducing this infection, in particular white mustard. Organic matter from cover crop biomass incorporated into the soil is a source of energy for microorganisms. Under its influence, the diversity, numbers and activity of microbes (including parasites and saprophytes) increase, which counteracts the dominance of pathogenic organisms, especially fungal ones (*Gaeumannomyces graminis, Pseudocercosporella herpotrichoides*) (Dawson and Bateman, 2000; Akinsanmi *et al*., 2004). The infection of the wheat stem base by a fungal disease complex increased during the duration of the monoculture experiment. This can be explained by the accumulation in the soil of wheat crop residue more severely infected by fungal pathogens which can survive on crop residue even 2-3 years, irrespective of weather conditions (Clear *et al*., 2000; Skoudiene and Nekrosiene, 2012). Wojciechowski (2008) as well as Wojtala and Parylak (2011) draw attention to the special role of cover crops of the family *Brassicacae*, which is due to their inhibitory effect on fungal pathogens.

CONCLUSIONS

The introduction of catch crops resulted in a clear reduction in the quantitative parameters of weed infestation. Growing white mustard and tansy phacelia caused the highest reduction in weed air-dry weight and soil seed bank, while this reduction was slightly lower in the case of the cultivation of legume-cereal mixture. The regenerating effects of catch crops in the three-year wheat monoculture were more effective under conventional tillage system with plowing compared to conservation tillage without plowing. Conservation tillage contributed to a significant increase in the number and air-dry weight of weeds in the spring wheat crop, regardless of the cover crop species.

Compared to the conventional tillage, the conservation tillage system without plowing influenced the greater biodiversity, increasing the number of weed species and weed density in the crop as well as the number of weed seeds in the soil in successive years of continuous cropping. Under both tillage systems, similar weed species dominated: *Viola arvensis, M. maritima ssp. inodora, Elymus repens,Chenopodium album* and *Stellaria media,* whereas plow tillage system and catch crops reduced plant density of these weed species. The health of spring wheat plants was independent of the tillage system and the infection of the stem base by a fungal disease complex increased with successive years of the monoculture. Catch crops, in particular white mustard, proved to be an effective method to reduce the degree of infection of spring wheat by fungal pathogens.

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اثرات گیاه پوششی و روش خاکورزی روی آلودگی به علف هرز و سلامت گندم بهاره

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چکیده

این مقاله نتایج پژوهشی را ارایه می کند که روی آلودگی به علف هرز و سلامت گندم بهاره ای بود که به مدت سه سال به صورت تک محصولی(تک کشتی) کاشته شد. خاک مزرعه محل آزمایش از نوع لس بود و در کلاس " مخلوط خوب برای گندم" (خاک کلاس ۲) قرار داشت. اولین عامل آزمایش در این پژوهش نوع گیاه پوششی (CC) بود که در برگیرنده این تیمارها بود:الف) تیمار شاهد بدون گیاه پوششی، ب) خردل سفید، ج) گیاه phacelia، و د) مخلوط گیاهان(لوبیا+ عدس بهاره + چاودار). عامل دوم سامانه وروش خاکورزی (TS) بود با دو تیمار الف) خاکورزی با شخم(PT) و ب) خاکورزی حفاظتی(CT). نتایج نشان داد که کاشت گیاه پوششی (به ویژه خردل سفید) می تواند روش موثری برای کم کردن اثرات منفی کاشت گندم بهاره به صورت تک کشتی باشد. علت آن است که گیاه پوششی هم باعث کاهش تعداد و کم شدن وزن علف ها در مزرعه می شود و هم پاتوژن های قارچی را که گندم بهاره را آلوده می کنند نسبت به دیگر موجودات خاک کم میکند. در این دوره سه ساله کشت تک محصولی گندم، اثرات باززایی(regenerating effects) گیاهان پوششی در شرایط روش رایج خاکورزی بیشتر از خاکورزی حفاظتی بود. همچنین، نتایج نشان داد که خاکورزی حفاظتی روی افزایش کمّی نشانگر های آلودگی به علف هرز در گندم و زیاد شدن تعداد بذر علف های هرز در خاک تاثیر معنی داری داشت. در مقایسه با خاکورزی حفاظتی، روش رایج خاکورزی با شخم منجر به تنوع زیستی کمتری در گونه های علف هرز شد. نیز، روش خاکورزی باعث نشد که تاثیر قابل تمایزی روی درجه آلودگی امراض قارچی پای ساقه (stem base) گندم پدید آید. بر پایه نتایج

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این آزمایش، ثابت شد که کاشت گیاهان پوششی (به ویژه خردل سفید) روش موثری در کاهش درجه آلودگی گندم بهاره به پاتوژن های قارچی است.

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