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THE OCCURRENCE OF FUNGI ON THE STEM BASE AND ROOTS OF SPRING WHEAT (*Triticum aestivum* L.) GROWN IN MONOCULTURE DEPENDING ON TILLAGE SYSTEMS AND CATCH CROPS

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A b s t r a c t

The present study was carried out in the period 2006-2008 based on an experiment established in 2005. The study evaluated the effect of conservation and plough tillage as well as of four catch crops on the level of infection by fungal pathogens of the stem base and roots of the spring wheat cultivar 'Zebra' grown in monoculture. The species composition of fungi colonizing the stem base and roots of spring wheat was determined. The split-plot design of the experiment set up on rendzina soil included plough tillage and conservation tillage with autumn and spring disking of catch crops. The experiment used four methods for regeneration of the spring wheat monoculture stand using the following: undersown red clover and Westerwolds ryegrass crops as well as lacy phacelia and white mustard stubble crops. Plots without catch crops were the control treatment.

Red clover and Westerwolds ryegrass catch crops as well as lacy phacelia and white mustard stubble crops had a significant effect on the decrease in the stem base and root infection index of spring wheat compared to the control without catch crops. The disease indices in the tillage treatments under evaluation did not differ significantly from one another. The stem base and roots of spring wheat were most frequently infected by fungi of the genus *Fusarium,* with *F. culmorum* being the dominant pathogen of cereals. Compared to conservation tillage, in plough tillage the pathogenic fungus *Bipolaris sorokiniana* was not found to occur on the stem base and roots. The Westerwolds ryegrass catch crop promoted the occurrence of *F. culmorum,* both on the stem base and roots of spring wheat.

Key words: conservation tillage, plough tillage, catch crop, spring wheat, pathogens, *Fusarium* spp., stem base, roots

INTRODUCTION

Conservation tillage changes physical, chemical and biological properties of soil. In the initial period of its use, this tillage system can also result in an increased level of infection of cereals by fungal pathogens (A r v i d s s o n , 1998; K i e c a n a et al. 2002; P a ł y s et al. 2004). In reduced tillage systems, plant residues remaining on the field surface and being a source of inoculum of many fungal species as well as high soil moisture content are conducive to increased infection of the stem base and roots of cereals by fungal pathogens (Ł a c i c o w a et al. 1985; R o t h r o c k , 1992; K i e c a n a et al. 2002; B a i l e y and L a z a r o v i t s , 2003). At the same time, conservation tillage has an effect on the increase in organic matter content and soil biological activity. As a result of higher numbers and higher diversity of antagonist microorganisms, the incidence of plant diseases can be reduced (S t u r z et al. 1997; H o l l a n d , 2004).

Growing cereals one after another involves the risk of the occurrence of increased infection of plants by stem base pathogens (W e s o ł o w s k i et al. 2004; B l e c h a r c z y k et al. 2006; K u r o w s k i and A d a m i a k , 2007). One of the methods to reduce the scale of this phenomenon is to introduce cover cropping (K r u p i n s k y et al. 2002; L e m a ń c z y k and W i l c z e w s k i , 2008). Many authors indicate white mustard as a plant that decreases the degree of plant infection by fungal pathogens in cereal monocultures (P a r y l a k , 2004; W o j c i e c h o w s k i , 2008; K w i a t k o w s k i , 2009). Damage to the stem base by fungal pathogens impedes nutrient and water supply to the plant. Diseased plants may have a disturbed growth pattern and poorer tillering ability as well as they turn white prematurely (K o r b a s , 2004). Fungi of the genus *Fusarium*, mainly *F. culmorum*, *F. avenaceum,* and *F. graminearum*, are considered to be the causal agents of stem base infection and root necrosis

in cereals (Łacicowa et al. 1990; Kiecana and Mielniczuk, 2001; Doohan et al. 2003; Kurowski and Adamiak, 2007).

The aim of the present study was to evaluate the effect of conservation and plough tillage as well as of various catch crops on the level of pathogen-induced infection of the stem base and roots of the spring wheat cultivar 'Zebra' grown in monoculture. The species composition of fungi colonizing the stem base and roots was also evaluated.

MATERIALS AND METHODS

The present study was carried out in the period 2006-2008 based on an experiment established in 2005 at the Bezek Experimental Farm (N: 51°19', E: 23° 25') belonging to the University of Life Sciences in Lublin. The experimental field was located on medium heavy mixed rendzina soil derived from chalk rock with the granulometric composition of medium silty loam. This soil with an alkaline pH (7.35 in 1 mol KCl), a high content of P (117.8) and K (242.4) as well as a very low content of magnesium (19.0) (the values given are expressed in mg×kg^{-1} of soil) and an organic carbon content of 24.7 g×kg^{-1}, was classified as soil quality class IIIb and defective wheat complex.

Total rainfall for the period from April to July in 2007 was distinctly higher than the long-term average for 1974-2003, while in 2008 it exceeded only slightly this average. The level of precipitation in 2006 was below the long-term average. Rainfall was at a low level in particular in June and July 2006. Mean air temperatures in all the years of the study were higher than the long-term average (Table 1).

Table 1.
Rainfall and air temperatures in months IV-VII during the period 2006-2008 as compared to the long-term means (1974-2003) according to the Meteorological Station at Bezek

Years	Months				Total
	IV	V	VI	VII	
	Rainfall in mm				
2006	25.1	56.7	23.2	26.2	131.2
2007	12.9	93.6	87.5	130.7	324.7
2008	47.9	74.2	38.4	93.9	254.4
Means for 1974–2003	40.1	53.0	77.6	80.3	251
	Temperature in °C				Mean
2006	8.9	13.5	16.7	21.7	15.2
2007	8.3	15.3	18.6	19.4	15.4
2008	9.1	12.7	17.4	18.3	14.4
Means for 1974–2003	7.6	13.6	16.2	17.9	13.8

The design of a static two-factor experiment, set up using the split-plot method in four replications, included plough tillage (A) and two conservation tillage methods with autumn (B) or spring (C) disking of catch crops. The other factor comprised four methods for regeneration of the spring wheat monoculture stand in the form of undersown crops (red clover, Westerwolds ryegrass) and stubble crops (lacy phacelia, white mustard). The plots without undersown crops and stubble crops were the control treatment. The harvest plot area was 30 m^2. Winter wheat grown in this field for 3 years was the forecrop for spring wheat. In 2005 spring wheat and all catch crops (both undersown crops and stubble crops) were sown and tillage was done in accordance with the methodological assumptions, treating this year as the preliminary year.

Plough tillage, preparing the field for spring wheat, started with skimming and harrowing after the harvest of the forecrop. Before the winter, ploughing was done to a medium depth burying catch crop biomass. In the spring harrowing was performed, and before sowing cultivating and harrowing were done.

Mineral fertilization was as follows: N-60+40 kg×ha^{-1}; P–30.5 kg×ha^{-1}; K– 74.7 kg×ha^{-1}. Phosphorus and potassium fertilization as well as the first portion of nitrogen were applied in the spring before sowing. The second dose of nitrogen at the rate of 40 kg ha^{-1} was incorporated at the beginning of shooting (BBCH 30-33). Spring wheat cv. 'Zebra' was sown at the rate of 5 million seeds per ha. Seeds were dressed with the seed dressing Panoctine 350 SL. Red clover cv. 'Dajana' (20 kg×ha^{-1}) and Westerwolds ryegrass cv. 'Mowester' (20 kg×ha^{-1}) were sown on the date of spring wheat sowing. Lacy phacelia cv. 'Stala' (20 kg×ha^{-1}) and white mustard cv. 'Borowska' (20 kg×ha^{-1}) were seeded following the harvest of spring wheat and after

performing post-harvest treatments in the second decade of August.

In the conservation tillage treatments (B and C), after the forecrop was harvested in the plots without undersown red clover and Westerwolds ryegrass, grubbing to a depth of 18-20 cm and harrowing were done. Subsequently, lacy phacelia and white mustard were sown, in the same way as in the plough tillage treatment. In one treatment the catch crops were disked before the winter (B), whereas in the other treatment (C) they were left as mulch for the winter and disking was done in the spring. In the treatments with autumn disking of catch crops (B), spring tillage was the same as in the plough tillage treatment. In the plots with the other conservation tillage treatment (C), the field was harrowed after disking had been done, and then harrowing was repeated before sowing spring wheat.

The wheat crop protection programme included the herbicide Chwastox Extra 300 SL 3.5 dm^3 ha^{-1} (300 g×dm^3 MCPA) – (BBCH 23-29) – and the fungicide Alert 375 SC 1 dm^3×ha^{-1} (125 g×dm^3 flusilazole and 250 g×dm^3 carbendazim) – (BBCH 26-29).

The health of spring wheat was evaluated at the milk stage (BBCH 73-77) in the years 2006-2008. 50 stems were randomly selected from each plot. The percentage of stems with necrosis symptoms on the lower internodes and roots was estimated. The level of infection was determined according to Eng-Chong Pua using a five-level scale (Łacicowa et al. 1990). The disease index was calculated according to Mc Kinney`s formula given by Łacicowa (1969).

The infected lower parts of the stem and roots were taken for laboratory examination. They were subjected to mycological analysis that was carried out by the dish method in accordance with the rules commonly accepted in phytopathology. To this end, 100 sections (5 mm) of diseased roots and stems (sampled earlier to evaluate the degree of infection) were placed on Petri dishes filled with mineral medium (Łacicowa, 1970). To identify fungi isolated from the infected plants, similar papers were used as in the study of Kiecana et al. (2009).

The obtained results were statistically analysed by analysis of variance. The mean values were compared by means of least significant differences using Tukey's test.

RESULTS AND DISCUSSION

The present study found an increasing trend in plant infection in the treatments with conservation tillage compared to plough tillage, which was confirmed by the calculated values of the infection index. In the conservation tillage plots with spring incorporation of catch crops, the disease index was slightly higher than in the conservation tillage treatments with autumn disking of catch crops. But the statistical analysis did not confirm the significance of differences (Table 2). Tillage reductions used by Arvidsson (1998) and confirmed by Kiecana et al. (2002) in spring barley growing were the cause of the worsening of health of this plant. Blecharczyk et al. (2006) as well as Małecka et al. (2009) found a higher value of the disease index in no-till winter wheat and winter triticale in comparison to plough tillage. On the other hand, Weber et al. (2001) reported a lower index of infection of spring and winter wheat by pathogens damaging the stem base under no-till conditions compared to plough tillage.

In the present study, the disease index determined for spring wheat in the treatments with undersown red clover as well as with white mustard and lacy phacelia stubble crops was significantly lower than in the control treatment without catch crops (Table 2). Parylak (2004) and Wojciechowski (2008) report that the ploughing in of stubble crops improves the health of spring and winter wheat, in particular the incorporation of white mustard biomass into the soil. After the incorporation of catch crops in a spring barley monoculture, Kwiatkowski (2009) also found the value of the stem base infection index to decrease. Majchrzak et al. (2004, 2005) noted an improvement in phytosanitary conditions in spring and winter wheat monocultures as a result of the incorporation of a catch crop from the Brassicaceae family.

In the first year of the study, the disease index was significantly lower than in the next two years of observation (Table 2). The interaction found between tillage systems and years indicates that the disease index was significantly higher in the plough tillage system only in 2007 compared to the years 2006 and 2008. On the other hand, in the conservation tillage treatments with autumn disking of catch crops, in 2006 the disease index of spring wheat was significantly lower than in 2008. In the last year of the study, the plant disease index was also significantly lower in the plough tillage treatments in comparison with the conservation tillage treatments with autumn incorporation of catch crops (Table 2).

In the control treatment without catch crops, in 2006 the disease index of spring wheat was significantly lower compared to the years 2006 and 2008. In 2006 the disease index in the treatments with undersown grass was also significantly lower than in 2008. In the other catch-cropped treatments, there was an increasing trend in the disease index of spring wheat in the years 2006 and 2008 compared to the first year of the study (Table 2).

Table 2.
Disease index values for spring wheat plants

Catch crops	Tillage system			Years			Mean
	[1]A	B	C	2006	2007	2008	
Control treatment	22.5	25.0	29.1	15.8	30.6	29.8	25.4
Red clover	17.9	23.2	19.1	19.1	20.3	20.8	20.1
Lacy phacelia	20.1	18.6	21.0	17.9	22.8	18.9	19.9
White mustard	16.2	17.7	20.8	17.5	19.1	18.1	18.2
Westerwolds ryegrass	21.6	24.6	22.6	16.7	23.1	29.0	22.9
Mean	19.6	21.8	22.5	17.4	23.2	23.3	–
Years 2006	14.7	18.4	19.0	LSD 0.05 catch crops 4.92 years 3.27 tillage systems x years 7.50 catch crops x years 10.59			
Years 2007	26.2	19.9	23.5				
Years 2008	17.8	27.1	25.0				

[1]A – plough tillage
B – conservation tillage with autumn disking of catch crops
C – conservation tillage with spring disking of catch crops

The mycological analysis of diseased spring wheat plants showed that, irrespective of the tillage system and type of catch crop, stem base and root necrosis was caused by fungi of the genus *Fusarium,* which is indicated by the number of isolates isolated from the investigated organs of spring wheat (Tables 3-5).

Over the study period of 2006-2008, the highest number of fungal isolates from the stem base was obtained from plants in the conservation tillage treatments in which catch crops were disked in the spring. The lowest number of fungal colonies was sampled from plants grown under the plough system (Table 3). Among the species isolated from the stem base, fungi of the genus *Fusarium* were obtained in great numbers; they were represented by *F. avenaceum*, *F. culmorum*, *F. crookwellense*, *F. equiseti*, *F. graminearum*, *F. oxysporum*, *F. poae*, and *F. sporotrichioides*. In the case of plants derived from the plough tillage treatments, fungi of the genus *Fusarium* accounted for 75.2% of total isolations. As regards plants sampled from the conservation tillage plots with autumn disking of catch crops, fungi of the genus *Fusarium* made up 79.1% of all isolates, whereas in the case of plants from the treatments where catch crops were disked in the spring, fungi of the genus *Fusarium* accounted for 71.2% of total isolations (Table 3). *F. culmorum* proved to be the dominant species among *Fusarium spp*. isolated from the stem base. Isolates of this fungus constituted 41.0% of colonies obtained from the ploughed plots, 43.2% of plants from the conservation tillage treatments with autumn disking of catch crops, and 58.5% of plants derived from the conservation tillage treatments with spring incorporation of catch crops (Table 3). This fungus proved to be the main cause of stem base disease in winter and spring wheat in the study of Weber et al. (2001); however, in addition to *F. culmorum*, *F. equiseti* also colonized the stem base in a high percentage, in particular in the plough tillage treatment. In the present study, this species was also noted much more frequently on the stem base of spring wheat grown using plough tillage (Table 3). *Fusarium culmorum* is a recognised pathogen of other cereal species grown under various conditions (Pałys et al. 2004; Kiecana et al. 2009). Fungi of the genus *Fusarium* may pose a significant threat to cereal plants under no-plough, which is indicated by the research of Sawińska and Małecka (2005) as well as of Małecka et al. (2009). Pathological changes caused by *Fusarium* spp. fungi in the study of Dłużniewska et al. (2003) occurred in the plots where catch crop biomass had been ploughed under in the autumn, compared to its incorporation in the spring. But Windels and Wiersma (1992) found no effect of the tillage system on spring wheat infection by *F. culmorum*.

The number of fungal isolates obtained from the roots of plants growing in all tillage treatments was similar, but the lowest number of fungal colonies was derived from plants growing in the conservation tillage treatments with spring disking of catch crops (Table 3).

The highest number of fungal colonies isolated from the roots of spring wheat, similarly as in the case of the stem base in all tillage treatments, was obtained from fungi of the genus *Fusarium* belonging 8 species (Table 3). *Fusarium* spp. isolates derived from the roots of plants growing in the ploughed plot accounted for 68.6% of total isolations, for 71.1% of all isolates sampled from the roots of plants growing in the conservation tillage treatments with autumn disking of

catch crops, and for 71.7% in the conventional tillage treatment with spring disking of catch crops (Table 3). Alongside *F. culmorum*, *F. avenaceum*, which is known to be harmful to wheat, proved to be a species damaging spring wheat roots in the tillage treatments under evaluation (Turner et al. 1999; Kurowski and Majchrzak, 2000; Pettitt et al. 2003; Kurowski and Adamiak, 2007; Fernandez et al. 2009; Weber and Kita, 2010). The occurrence of the above-mentioned species in all tillage treatments confirms the high competitive ability of these fungi enabling them to survive in soil, which primarily causes roots to be infected (Łacicowa and Kiecana, 1987). The deep burial of post-harvest residues, which are a source of inoculum of various *Fusarium* spp., is a treatment that reduces infection of cereals by these fungi (Parry et al. 1995). Tillage reductions consisting in replacing ploughing with disking create favourable conditions for the development of fungi of the genus *Fusarium* (Truszkowska et al. 1980). This should provide an explanation for the more numerous isolations of fungi of the genus *Fusarium* from the roots of plants derived from the conventional tillage treatments where ploughing was not done (Table 3). *F. crookwellense,* considered to be a pathogen of cereals, was not found to occur on the roots and stem base of plants growing in the conservation tillage treatment with spring disking of catch crops (Kiecana and Mielniczuk, 2001; Kiecana et al. 2003; Mielniczuk, 2008).

The species *F. oxysporum* was isolated from the stem base and roots of plants in each tillage treatment (Table 3). This fungus is not considered to be a pathogen of cereal plants which only play the role of secondary host making it easier for *F. oxysporum* to survive without the primary host (Kiecana et al. 2003, 2009). Isolates of this species isolated from the stem base and roots were found to have a significant percentage in the case of plants growing in the conservation tillage treatments with autumn incorporation of catch crops (Table 3).

Plough tillage eliminated the occurrence of *B. sorokiniana*. Isolates of this fungus were obtained only from spring wheat plants in the conservation tillage treatments. *Bipolaris sorokiniana* is a serious threat to cereals, in particular barley and wheat, in different climatic regions of the world and since the 1970's also for barley and wheat grown in Poland (Windels and Wiersma, 1992; Łacicowa et al. 1993; Kiecana et al. 2002; Sheng-Xiulang et al. 1999; Fernandez et al. 2000; Perello et al. 2002; Kiecana and Cegiełko, 2007).

Compared to conservation tillage, plough tillage eliminated *Rhizoctonia solani* on the stem base of spring wheat (Table 3). The fungus *Rhizoctonia solani* derived from the roots of plants growing in all tillage treatments is considered to be an additional infectious factor causing base stem diseases of cereals, including wheat (Łacicowa et al. 1993; Wagner, 1996). This fungus infects the tips of young roots in the soil, which in effect inhibits plant growth and yield (Łacicowa et al. 1990). This species was not noted on the stem base of plants derived from the plough tillage treatments. It should be presumed that this tillage system was beneficial for the development of fungi of the genus *Trichoderma* and *Penicillium*, well-known antagonists to *R. solani*, whose isolates made up 8.3% of the total number of isolates obtained from the stem base, which is confirmed by Majchrzak (1985) as well as by Pięta and Kęsik (2005).

In the treatments with undersown red clover crops, the percentage of fungal species of the genus *Fusarium* isolated from the stem base was 65.5% and it was distinctly lower than in the other catch-cropped treatments (Table 4). A reverse relationship was found with respect to the percentage of these species isolated from the roots of spring wheat. In the treatments with red clover catch crops, the percentage of fungi of the genus *Fusarium* was 72.8% of total isolations and it was higher than in the other treatments under evaluation (Table 5). The application of lacy phacelia and white mustard as stubble crops was found to result in a decrease in the percentage of fungi of the genus *Fusarium* derived from the roots of spring wheat in comparison with the control and with plants obtained from the treatments with red clover and Westerwolds ryegrass (Table 5).

As regards the stand regeneration methods in the form of undersown crops compared to the control, it was found that the application of undersown red clover as well as of lacy phacelia and white mustard stubble crops contributed to a reduction in the development of *F. culmorum* on the roots of spring wheat (Table 5). The percentage of isolates of this fungus isolated from the roots of control plants was 48.3%, whereas in the treatment with red clover it was 45.4%, with lacy phacelia 40.7%, and with white mustard 40.2% (Table 5). The beneficial effect of the white mustard stubble crop on the health of roots of spring barley and spring wheat was also found by Lemańczyk and Wilczewski (2006) as well as by Wojciechowski (2008). The species *F. culmorum* had a significant percentage among the species damaging the stem base and roots of wheat grown with undersown Westerwolds ryegrass compared to the control treatment, which is indicated by the high percentage of isolates of this pathogen obtained from these organs (Tables 4-5). *F. sporotrichioides*, considered to be a weak pathogen of cereals, was also isolated from infected spring wheat plants (Kiecana and Kocyłak, 1999).

The species *Trichoderma koningii* is thought to be an effective mycoparasite on species of the genus *Fusarium,* in particular *F. culmorum* (Ł a c i c o w a and P i ę t a , 1985). The percentage of *F. culmorum* isolates was the lowest on the stem base (Tables 4-5) in the treatments with lacy phacelia and, additionally, on the roots in the treatments with white mustard where the highest percentage proportion of isolates of the above-mentioned species was found. M a j c h r z a k (1985) also reports that a large number of fungi of the genus *Trichoderma* and *Penicillium* determine the resistance of the soil environment to pathogens causing root and stem base rots. Plant biomass incorporated into the soil, contributing to increased soil biological activity, may lead to an improvement in its phytosanitary condition (L e m a ń c z y k and W i l c z e w s k i , 2008).

The species *Bipolaris sorokiniana* could have participated in damaging the stem base and roots of plants from the control treatment and from the treatment with undersown Westerwolds ryegrass (Tables 4-5). This fungus can also infect stems and roots of grasses of the genus *Lolium* and can be a potential source of inoculum for the main crop (H e n g and Y u e n , 1989, according to C e g i e ł k o , 2006).

Table 3.
Fungi isolated from the stem base and roots of spring wheat depending on tillage system (2006-2008)

Fungus	Tillage system					
	Stem base Number of isolates in 2006-2008 (%)			Root Number of isolates in 2006-2008 (%)		
	[1]A	B	C	A	B	C
Alternaria alternata (Fr.) Keissler	41 (7.7)	47 (7.5)	61 (9.7)	70 (11.8)	49 (8.1)	52 (8.8)
Aureobasidium pullulans (de Bary) Arnaud.	7 (1.3)	2 (0.3)	38 (6.0)	12 (2.0)	18 (3.0)	14 (2.4)
Bipolaris sorokiniana (Sacc.) Shoem.	–	7 (1.1)	8 (1.3)	–	4 (0.7)	3 (0.5)
Cladosporium cladosporioides (Fres.) de Vries	–	–	6 (1.0)	–	–	–
Chaetomium globosum Kunze	5 (0.9)	5 (0.8)	–	14 (2.4)	1 (0.1)	–
Epicoccum nigrum Link	18 (3.4)	7 (1.1)	9 (1.4)	17 (2.9)	13 (2.2)	9 (1.5)
Fusarium avenaceum (Fr.) Sacc.	85 (16.0)	69 (11.1)	35 (5.5)	43 (7.2)	35 (5.8)	48 (8.1)
Fusarium culmorum (W. G. Sm.) Sacc.	218 (41.0)	269 (43.2)	368 (58.5)	264 (44.4)	252 (41.7)	303 (51.4)
Fusarium crookwellense Burges, Nelson, Tousson	6 (1.1)	5 (0.8)	–	5 (0.8)	3 (0.5)	–
Fusarium equiseti (Corda) Sacc.	42 (7.9)	12 (1.9)	3 (0.5)	–	–	10 (1.7)
Fusarium graminearum Schwabe	–	10 (1.6)	–	1 (0.2)	3 (0.5)	–
Fusarium oxysporum Schl.	35 (6.6)	108 (17.4)	31 (4.9)	81 (13.6)	123 (20.4)	46 (7.8)
Fusarium poae (Peck.) Wollenw.	–	8 (1.3)	8 (1.3)	–	6 (1.0)	6 (1.0)
Fusarium sporotrichioides Sherb.	14 (2.6)	11 (1.8)	3 (0.5)	14 (2.4)	7 (1.2)	10 (1.7)
Gilmaniella humicola Barron	1 (0.2)	1 (0.2)	–	4 (0.7)	4 (0.7)	–
Humicola grisea Traaen	–	3 (0.5)	–	–	1 (0.1)	–
Mucor hiemalis Oud.Wehmer	3 (0.6)	3 (0.5)	3 (0.5)	10 (1.7)	10 (1.7)	10 (1.7)
Penicillium verrucosum Dierckx var. *cyclopium* (Westling.) Samson , Stolk et Hadlok	13 (2.4)	8 (1.3)	20 (3.2)	7 (1.2)	19 (3.1)	20 (3.4)
Rhizoctonia solani Kühn	–	26 (4.2)	11 (1.7)	1 (0.2)	7 (1.2)	16 (2.7)
Talaromyces flavus (Ben.) Stolk et Samson	–	–	–	9 (1.5)	–	11 (1.9)
Trichoderma aureoviride Rifai	1 (0.2)	–	–	3 (0.5)	–	–
Trichoderma koningii Oud.	–	1 (0.2)	9 (1.4)	–	16 (2.6)	11 (1.9)
Trichoderma viride Pers ex S. F. Gray	30 (5.7)	12 (1.9)	8 (1.3)	22 (3.7)	25 (4.1)	9 (1.5)
Non-sporulating forms	13 (2.4)	8 (1.3)	8 (1.3)	17 (2.8)	8 (1.3)	12 (2.0)
Total number of isolates in 2006-2008	532	622	629	594	604	590

[1]A – plough tillage
B – conservation tillage with autumn disking of catch crops
C – conservation tillage with spring disking of catch crops

Table 4.
Fungi isolated from the stem base of the spring wheat cultivar 'Zebra' depending on catch crop (2006-2008)

Fungus	Catch crop Number of isolates in 2006-2008 (%)				
	control	red clover	lacy phacelia	white mustard	Westerwolds ryegrass
Alternaria alternata (Fr.) Keissler	48 (11.9)	60 (17.1)	17 (5.1)	7 (1.9)	17 (5.1)
Aureobasidium pullulans (de Bary) Arnaud.	29 (7.2)	1 (0.3)	6 (1.8)	1 (0.3)	10 (3.0)
Bipolaris sorokiniana (Sacc.) Shoem.	12 (3.0)	2 (0.6)	–	1 (0.3)	–
Chaetomium globosum Kunze	–	5 (1.4)	2 (0.6)	1 (0.3)	2 (0.6)
Cladosporium cladosporioides (Fres.) de Vries	–	–	1 (0.3)	5 (1.3)	–
Epicoccum nigrum Link	2 (0.5)	10 (2.8)	3 (0.9)	19 (5.3)	
Fusarium avenaceum (Fr.) Sacc.	44 (11.0)	39 (11.0)	25 (7.5)	59 (16.4)	22 (6.5)
Fusarium crookwellense Burges, Nelson, Tousson	5 (1.2)	2 (0.6)	–	4 (1.1)	–
Fusarium culmorum (W.G.Sm.) Sacc.	181 (45.0)	170 (48.1)	140 (42.1)	167 (46.5)	197 (59.0)
Fusarium equiseti (Corda) Sacc.	11 (2.7)	4 (1.1)	17 (5.1)	25 (7.0)	–
Fusarium graminearum Schwabe	7 (1.7)	3 (0.8)	–	–	–
Fusarium oxysporum Schl.	29 (7.2)	3 (0.8)	81 (24.3)	31 (8.7)	30 (9.0)
Fusarium poae (Peck.) Wollenw.	10 (2.5)	–	–	–	6 (1.8)
Fusarium sporotrichioides Sherb.	1 (0.2)	11 (3.1)	9 (2.7)	3 (0.8)	4 (1.2)
Gilmaniella humicola Barron	2 (0.5)	–	–	–	–
Humicola grisea Traaen	–	–	–	2 (0.6)	1 (0.3)
Mucor hiemalis Oud.Wehmer	–	3 (0.8)	–	–	6 (1.8)
Penicillium verrucosum Dierckx var. *cyclopium* (Westling.) Samson , Stolk et Hadlok	3 (0.7)	9 (2.5)	11 (3.3)	3 (0.8)	15 (4.5)
Rhizoctonia solani Kühn	15 (3.7)	16 (4.5)	4 (1.2)	2 (0.6)	–
Talaromyces flavus (Ben.) Stolk et Samson	–	–	–	–	–
Trichoderma aureoviride Rifai	–	–	1 (0.3)	–	–
Trichoderma koningii Oud.	2 (0.5)	–	4 (1.2)	2 (0.6)	2 (0.6)
Trichoderma viride Pers ex S. F. Gray	–	9 (2.5)	3 (0.9)	19 (5.3)	19 (5.7)
Non-sporulating forms	2 (0.5)	7 (2.0)	9 (2.7)	8 (2.2)	3 (0.9)
Total number of isolates in 2006-2008	403	354	333	359	334

Table 5.
Fungi isolated from the roots of the spring wheat cultivar 'Zebra' depending on catch crop (2006-2008)

Fungus	Catch crop Number of isolates in 2006-2008 (%)				
	control	red clover	lacy phacelia	white mustard	Westerwolds ryegrass
Alternaria alternata (Fr.) Keissler	50 (14.0)	24 (7.0)	47 (12.1)	21 (6.9)	29 (7.3)
Aureobasidium pullulans (de Bary) Arnaud.	16 (4.5)	1 (0.3)	13 (3.4)	5 (1.6)	9 (2.3)
Bipolaris sorokiniana (Sacc.) Shoem.	4 (1.1)	–	–	–	3 (0.8)
Chaetomium globosum Kunze	–	1 (0.3)	5 (1.3)	1 (0.3)	8 (2.0)
Epicoccum nigrum Link	2 (0.6)	5 (1.5)	6 (1.6)	25 (8.2)	1 (0.3)
Fusarium avenaceum (Fr.) Sacc.	16 (4.5)	50 (14.6)	21 (5.4)	13 (4.2)	26 (6.5)
Fusarium crookwellense Burges, Nelson, Tousson	3 (0.8)	1 (0.3)	1 (0.3)	3 (1.0)	–
Fusarium culmorum (W.G.Sm.) Sacc.	172 (48.3)	155 (45.5)	158 (40.7)	123 (40.2)	211 (53.1)
Fusarium equiseti (Corda) Sacc.	–	1 (0.3)	–	–	9 (2.3)
Fusarium graminearum Schwabe	2 (0.6)	2 (0.6)	–	–	–
Fusarium oxysporum Schl.	51 (14.3)	36 (10.6)	77 (19.8)	63 (20.6)	23 (5.8)
Fusarium poae (Peck.) Wollenw.	4 (1.1)	–	2 (0.5)	–	6 (1.5)
Fusarium sporotrichioides Sherb.	4 (1.1)	3 (0.9)	6 (1.5)	9 (2.9)	9 (2.3)
Gilmaniella humicola Barron	2 (0.6)	–	–	–	6 (1.5)
Humicola grisea Traaen	–	–	–	–	1 (0.3)
Mucor hiemalis Oud.Wehmer	–	9 (2.6)	–	–	21 (5.3)
Penicillium verrucosum Dierckx var. *cyclopium* (Westling.) Samson , Stolk et Hadlok	15 (4.2)	8 (2.3)	11 (2.8)	6 (2.0)	6 (1.5)
Rhizoctonia solani Kühn	7 (2.0)	4 (1.2)	8 (2.1)	1 (0.3)	4 (1.0)
Talaromyces flavus (Ben.) Stolk et Samson	–	1 (0.3)	3 (0.8)	2 (0.7)	14 (3.5)
Trichoderma aureoviride Rifai	–	1 (0.3)	2 (0.5)	–	–
Trichoderma koningii Oud.	2 (0.6)	3 (0.9)	10 (2.6)	10 (3.3)	2 (0.5)
Trichoderma viride Pers ex S. F. Gray	2 (0.6)	26 (7.6)	12 (3.1)	11 (3.6)	5 (1.2)
Non-sporulating forms	4 (1.1)	10 (2.9)	6 (1.5)	13 (4.2)	4 (1.0)
Total number of isolates in 2006-2008	356	341	388	306	397

CONCLUSIONS

1. Tillage system did not have a significant effect on the value of the index of spring wheat infection by pathogens damaging the stem base and roots.
2. Undersown red clover crops as well as white mustard and lacy phacelia stubble crops significantly decreased the value of the stem base and root infection index of spring wheat.
3. The species *Fusarium culmorum* and *F. avenaceum* were the cause of damage to the stem base and root in the plough and conservation treatments under comparison as well as in the catch-cropped treatments.
4. Compared to conservation tillage, plough tillage decreased the occurrence of *F. culmorum* on the stem base of spring wheat. It also proved to be

more effective in reducing infection of spring wheat roots by fungi of the genus *Fusarium*.

5. Plough tillage eliminated the pathogenic species *Bipolaris sorokiniana* from the stem base and roots of spring wheat.
6. Under the conditions when spring wheat crops are threatened by *F. culmorum*, it is inadvisable to use Westerwolds ryegrass as an undersown crop.

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Występowanie grzybów na podstawie źdźbła i korzeniach pszenicy jarej (*Triticum aestivum* L.) uprawianej w monokulturze w zależności od systemów uprawy roli oraz międzyplonów

Streszczenie

Badania przeprowadzono w latach 2006-2008, na bazie doświadczenia założonego w 2005 roku. W pracy oceniano wpływ uprawy konserwującej i płużnej oraz czterech międzyplonów na stopień porażenia przez patogeny grzybowe podstawy źdźbła i korzeni pszenicy jarej odmiany Zebra uprawianej w monokulturze. Określono skład gatunkowy grzybów zasiedlających podstawę źdźbła i korzenie pszenicy jarej. Schemat doświadczenia założonego na glebie rędzinowej metodą split-plot uwzględniał uprawę płużną, uprawę konserwującą prowadzoną z jesiennym oraz z wiosennym talerzowaniem międzyplonów. Uwzględniono cztery sposoby regeneracji stanowiska w monokulturze pszenicy jarej: w postaci wsiewek międzyplonowych koniczyny czerwonej i życicy westerwoldzkiej oraz międzyplonów ścierniskowych facelii błękitnej i gorczycy białej. Obiekt kontrolny stanowiły poletka bez międzyplonów.

Wsiewka międzyplonowa koniczyny czerwonej oraz międzyplony ścierniskowe gorczycy białej i facelii błękitnej wpłynęły istotnie na zmniejszenie indeksu porażenia podstawy źdźbła i korzeni pszenicy jarej w porównaniu z kontrolą bez międzyplonów. Wskaźniki chorobowe w ocenianych obiektach uprawowych nie różniły się istotnie między sobą. Podstawa źdźbła i korzenie pszenicy jarej najczęściej były porażane przez grzyby z rodzaju *Fusarium,* z dominującym patogenicznym dla zbóż *F. culmorum.* W uprawie płużnej w porównaniu z konserwującą, nie stwierdzono występowania na podstawie źdźbła i korzeniach patogenicznego *Bipolaris sorokiniana.* Wsiewka międzyplonowa życicy westerwoldzkiej sprzyjała występowaniu *F. culmorum,* zarówno na podstawie źdźbła jak i korzeniach pszenicy jarej.