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EFFECTS OF TILLAGE SYSTEM AND FORECROP TYPE ON FREQUENCY OF *Fusarium culmorum* AND *F. avenaceum* OCCURRENCE ON CULM BASE OF SOME WINTER WHEAT (*Triticum aestivum L.)* CULTIVARS

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A b s t r a c t

In the years 2001 – 2003, there were analyzed relations between the number of *Fusarium culmorum* and *F. avenaceum,* fungi found on culm base parts of stalks of seven winter wheat cultivars, and preceding crop type as well as the cultivation system. The research was carried out in Poland, on light soil plots of a Lower Silesia-based experimental station subordinate to the Institute of Soil Science and Plant Cultivation (IUNG). The log-linear and correspondence analyses proved varying immunity of particular wheat cultivars to *F. culmorum* and *F. avenaceum* fungi. There were also observed significant differences in *Fusarium* diseases of wheat as dependent on precipitation and temperature in the growing season. The Kobra cultivar was highly resistant to *F. avenaceum*. The lowest amounts of *F. culmorum* fungi were detected in the culm base parts of the Izolda cultivar. The cultivation of corn, as a preceding crop for oats and for spring wheat, did significantly differentiate varieties of fungi in the cultivation systems examined. In the plough cultivation system, wheat was mainly infected by *Fusarium culmorum,* whereas in direct sowing, particular cultivars of wheat were mostly infected by *F. avenaceum.*

Keywords: culm base diseases, tillage system, *Fusarium,* winter wheat cultivars

INTRODUCTION

Recently, fusarium diseases (scab) of wheat ears have become very common all over the world. Considerable diversity of Fusarium ssp. makes fungi control in wheat plantations very difficult. Currently, *Fusarium culmorum, F. graminearum, F. avenaceum, F. poae* and *Microdochium nivale* prevail in European countries (D o o h a n et al. 2003). Wheat sprout infection reduces crops by 7-17%. The infection of plant roots and stalks in their later stage of development results in 10-30% crop loss, while infection of ears by *Fusarium* fungi can cause 30-70% loss (M a r t i n and J o h n s t o n, 1982; I n c h and G i l b e r t, 2003). The application of plant protection measures can reduce the occurrence of diseases but it can not completely prevent crop losses. Therefore, the most effective method of protection against fusarium diseases seems to be cultivation of pest resistant cereal cultivars (R u c k e n b a u e r et al. 2001). According to Mesterhazy (2001), there are seven physiological components of pest resistance, namely: (I) resistance to initial infection, (II) resistance to spread within a spike, (III) resistance to kernel infestation (IV) resistance to drying-up, (V) resistance to ear necrosis above the site of infection, (VI) resistance to toxin accumulation, (VII) tolerance . The investigation conducted in Germany (Lower Saxony) proved that the main factor which controls contamination of grain with mycotoxins (produced by fungi of the *Fusarium* genus) is an appropriate preceding crop, followed by proper selection of plant cultivars and the method of cultivation (K o c h et al. 2006). Nevertheless, the main factor, which determines the frequency of occurrence of fusarium ear diseases, is the level of precipitation in the course of the wheat flowering stage. Moreover, it was found that climate conditions influence competitiveness between fungi species (D o o h a n et al. 2003). Some authors, comparing particular tillage systems, report that the ploughless cultivation system promotes the intensity

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of ear infection (Dill-Macky and Jones, 2000; Champeil et al. 2004). Other papers point out the fact that a reduction in the frequency of occurrence of wheat diseases caused by *Fusarium ssp*. can be achieved by simplified tillage systems. Fungi of the *Fusarium* genus feature diverse invasiveness and mutual competitiveness (Pettitt et al. 2003). Particular plant cultivars differ in their immunity to *Fusarium ss*. (Koch et al. 2006).

The infection of grain is, to a high degree, related to the infection of the culm base (Bateman et al. 2007). The latter one, when infected by *Fusarium culmorum, F. avenaceum* or *F. graminearum*, can cause a disease of the whole wheat stem as well as of the ear (Clement and Pary 1998, Schlüter et al., 2006). Competitiveness of fungi belonging to *Fusarium ssp.* can considerably vary depending on the tillage system. The aim of the study was to estimate the occurrence of *Fusarium ssp.* fungi on the culm base of wheat as dependent on weather conditions, forecrop, tillage system, and plant cultivars grown.

MATERIALS AND METHODS

The research was carried out in the years 2001-2003 in Lower Silesia. Field experiments followed the split-split-plot design with 4 replications, on heavy loamy sand soil deposited on a light loamy layer. There were examined three factors, i.e. tillage methods, preceding crop types and wheat cultivars. Factor # 1 involved different methods of tillage: a) simplified tillage, ploughless, in which the upper layer of soil was loosened down to 15 cm; b) conventional tillage, including ploughing to a depth of 25 cm; and c) direct sowing. Factor # 2 covered a) oats and b) spring wheat, applied as forecrops. Factor # 3 related to selected winter wheat (*Triticum aestivum* L.) cultivars: Elena, Maltanka, Kobra, Aleta, Mikon, Izolda and Sakwa. The forecrops were preceded by corn. In the milky-wax maturity phase (78-81 in the Zadoks scale), out of 100 plants harvested from each experimental plot there were randomly sampled 20 infected stalks for mycological analysis. The sampled plants had their culm-base parts cut off and disinfected with 0.5% sodium hypochlorite solution for 1 minute. Then, after removal of the top sections, 5 inoculums were cut off which were put on PDA medium in Petri dishes. The operations were carried out in a relatively aseptic environment, according to the commonly accepted standards. The colonies of fungi were identified to determine particular species, as described in the monographs available (Booth, 1971; Nelson et all. 1983). Weather parameters in particular years and months of the experiment are shown in Table 1. Meteorological data for IUNG's Experimental Station in Jelcz-Laskowice were obtained from the Institute of Meteorology and Water Management (IMGW), Wrocław Branch.

The relations between the number of *F. culmorum* or *F. avenaceum* colonies and the forecrop type, tillage method, wheat cultivar and years of cultivation were evaluated by means of log-linear analysis, according to Everit (1977) and Goodman (1978). All significant differences between the actual and expected values were considered as the evidence of interactions existing between particular factors. To compare the susceptibility of particular cultivars to *F. culmorum* and *F. avenaceum* infection, depending on different tillage systems and preceding crop types, the correspondence analysis was used. The mentioned analysis enables the presentation of data originally shown in six-dimensional space (2 forecrop types x 3 tillage systems) in the form of two-dimensional diagrams, in a way which illustrates maximum variability of the genotypes examined. The correspondence analysis enables the assessment of the structure of relations between the tillage systems and forecrops in two-dimensional space, without any loss of information about the variability of the factors in seven-dimensional space, formed by the cultivars examined.

RESULTS

The optimal statistic model, determining the effect of the selected cultivar and forecrop as well as applied tillage systems on the number of isolates of *Fusarium culmorum* and *F. avenaceumn* fungi, was analyzed using the χ^2 test for general effects and for particular interactions between the factors examined. Because of the fact that statistical values, calculated for the model as interactions of the second, third and fourth order, were significant, the hypothesis about the absence of any effect of year of experiment, tillage system, preceding crop type and winter wheat cultivar on the number of *Fusarium culmorum* and *F. avenaceum* fungi was rejected et the level p <0.01. The operation of including the interactions of the second and third order did considerably improve matching up the model, which was made evident by significant values of the χ^2 test. Significance of the main effects and of particular factors involved the experiment was assessed by data analysis shown in Table 2. The analysis proved considerable differences in the number of isolates of *F. culmorum* or *F. avenaceum* found on wheat cultivars in particular years of investigation. This is the evidence that weather conditions do significantly influence the occurrence of the fungi in question. Moreover, it was shown that the significant variation in number of *F. aveanceum* isolates resulted from the type of forecrop. Yet, the log-linear analysis excludes the interaction between the tillage system and preceding crop used. The numerical force of *F. culmorum* or *F. avenaceum* was significantly related to the tillage system, regardless the type of preceding crop applied.

There was introduced an iterative procedure to adjust the model to the actual number of fungi. The procedure was finished when the differences between the model and actual boundary distribution did not exceed the criterion of convergence amounting to 0.01.

In practice, the procedures described above refine the model by elimination of insignificant interactions between the variable data. Matching up the model requires the calculation of expected values which reflect the boundary numbers of fungi.

In 2003, with increased rainfall during the vegetation season, the wheat cultivars were colonized mostly by *F. avenaceum,* whereas in 2002, after reduced rainfall in September and October 2001, *F. culmorum* dominated (Tables 1, 3). Oats, applied as a preceding crop, relatively increased the number of *F. avenaceum,* as compared to spring wheat (Table 4). However, the number of *F. culmorum* proved to be not affected by the preceding crop type applied. The plough tillage favours the dominance of *F. culmorum.* Direct sowing increased the occurrence of *Fusarium avenaceum* (Table 5). Particular cultivars of winter wheat differed in their susceptibility to infection of the culm base with *F. culmorum* and *F. avenaceum.* The Kobra cultivar proved to be relatively resistant to *F. avenaceum,* but highly susceptible to infection with the pathogen. Table 5 shows that the Izolda cultivar was considerably resistant to *F. culmorum*.

The further part of the paper is devoted to the determination of the structure of dependence of *F. culmorum* and *F. avenaceum* numbers on the experimental factors analyzed, i.e. precipitation characteristics in the growing season, soil tillage system, preceding crop type as well as plant cultivars. To this end, there was applied the analysis of correspondence, brought into general use by Hill (1974). It is often called analysis of homogeneity or optimal scaling, reciprocal averaging, optimal scaling, quantification method. The analysis aims et presenting a set of points, in our case it is the set of particular cultivars of winter wheat, in the space reduced to two or maximum three dimensions. Therefore, the reaction of individual cultivars to the effects of the analyzed factors is presented in the form of two-dimensional diagrams, with full information about their effects on the frequency of occurrence of *F. culmorum* and *F. avenaceum*, the source of culm base diseases (Figs 1 and 2).

When considering the arrangement of particular wheat cultivars in two-dimensional space (Fig. 1), it is noticeable that the Sakwa, Elena and Mikon cultivars, located on the left side of the system of coordinates, considerably differ in their susceptibility to *F. avenaceum* from the Kobra and Maltanka cultivars located on the right side. The Aleta cultivar differs in its reaction to the fungi responsible for culm base diseases, as compared to other genotypes. The point attributed to Izolda is located close to the origin of the coordinate system. It means that the cultivar profile represents average susceptibility to fusariosis infection. A comparison between Fig. 1 and Fig. 2 leads to the conclusion that the number of occurrence of *F. culmorum* and *F. avenaceum* on the culm base parts of plants significantly differs depending on the soil tillage system used. The evidence for this statement is a considerable distance between the respective points in two-dimensional space. The considerable distances between the points related to particular tillage systems show that there are different effects of tillage systems on the variability of *F. avenaceum* and *F. culmorum* numbers (Figs 3, 4).

Table 1

Total rainfall (mm) and air temperature (°C) during the wheat growing period (T – temperature, O – precipitation)

Year		Month												Total
		9	10	11	12	1	2	3	4	5	6	7	8	
2002/	T	16.5	9.1	2.2	1.3	-1.0	3.3	4.7	11.8	15.6	18.1	16.7	18.5	116.8
2003	O	33.5	24.3	36.3	36.1	34.6	34.6	76.9	17.8	76.5	38.1	165.8	45.4	619.9
2001/	T	12.8	12.1	6.5	2.0	0.0	0.9	3.2	7.7	14.8	15.1	19.2	19.4	113.7
2002	O	17.3	10.9	47.9	34.8	20.7	18.1	60.3	40.9	68.8	71.0	140.8	46.7	578.2
2000/	T	12.5	12.1	3.4	-2.2	-0.2	4.3	5.0	8.3	17.2	18.1	20.5	20.4	119.4
2001	O	79.2	22.5	33.2	31.4	24.0	58.2	15.9	44.5	78.8	53.1	38.2	85.5	565.1
1956-2000	T	13.5	8.8	3.7	0.1	-1.5	-0.3	3.2	8.0	13.3	16.6	18.2	17.5	101.1
	O	47.6	38.4	38.3	34.3	27.2	25.5	31.3	37.6	61.3	71.4	80.0	67.7	560.6

Table 2

Tests of partial association and interaction between investigated factors.

Effect	*Degrees of freedom*	*Fusarium culmorum* χ^2 *Partial association*	*Fusarium culmorum* P	*Fusarium avenaceum* χ^2 *Partial association*	*Fusarium avenaceum* P
Cultivar (1)	6	125.35	0.0000	102.11	0.0000
Forecrop (2)	1	1.11	0.2921	26.27	0.0000
Years (3)	2	3185.41	0.0000	454.62	0.0000
Tillage systems (4)	2	21.65	0.0000	58.36	0.0000
1 x 2	6	45.99	0.0000	66.83	0.0000
1 x 3	12	37.83	0.0001	156.76	0.0000
1 x 4	12	83.60	0.0000	35.18	0.0004
2 x 3	2	5.13	0.0769	53.45	0.0000
2 x 4	2	2.958	0.2278	0.72	0.6963
3 x 4	4	94.18	0.0000	100.47	0.0000
1 x 2 x 3	12	24.40	0.0179	175.80	0.0000
1 x 2 x 4	12	55.12	0.0000	58.59	0.0000
1 x 3 x 4	24	116.27	0.0000	269.45	0.0000
2 x 3 x 4	4	9.48	0.0502	16.18	0.0027

Table 3

Variability of the number of *F. avenaceum* and *F. culmorum* in particular years of investigation

Cultivars vs. *F. avenaceum*								
	Elena	Maltanka	Kobra	Aleta	Mikon	Izolda	Sakwa	Total
2001	110	262	76	140	190	161	145	1084
2002	37	58	30	89	45	55	126	440
2003	180	192	177	173	149	186	228	1285
Total	327	512	283	402	384	402	499	2809
Cultivars vs. *F. culmorum*								
	Elena	Maltanka	Kobra	Aleta	Mikon	Izolda	Sakwa	Total
2001	133	82	119	64	142	109	91	740
2002	387	384	462	276	378	214	322	2423
2003	0	2	5	0	3	5	4	19
Total	520	468	586	340	523	328	417	3182

Table 4

Variability of the number of *F. avenaceum* and *F. culmorum* as dependent on forecrop

Cultivars vs. *F. avenaceum*								
Preceding crop	Elena	Maltanka	Kobra	Aleta	Mikon	Izolda	Sakwa	Total
Oats	206	227	139	227	194	256	293	**1542**
Wheat	121	285	144	175	191	146	206	1268
Total	327	**512**	**283**	402	384	402	499	2809
Cultivars vs. *F. culmorum*								
Preceding crop	Elena	Maltanka	Kobra	Aleta	Mikon	Izolda	Sakwa	Total
Oats	268	270	303	140	251	118	211	1561
Wheat	252	198	283	200	272	210	206	**1621**
Total	520	468	**586**	340	523	**328**	417	3182

Table 5

Variability of the number of *F. avenaceum* and *F. culmorum* as dependent on tillage system

	Cultivars vs. *F. avenaceum*							
Tillage type	Elena	Maltanka	Kobra	Aleta	Mikon	Izolda	Sakwa	Total
Ploughing	114	159	59	123	106	131	136	828
Simplified	70	157	93	135	132	112	150	849
No-tillage	143	196	131	144	146	159	213	**1132**
Total	**327**	512	**283**	402	384	402	499	2809
	Cultivars vs. *F. culmorum*							
Tillage type	Elena	Maltanka	Kobra	Aleta	Mikon	Izolda	Sakwa	Total
Ploughing	228	138	162	113	221	124	188	**1174**
Simplified	151	168	252	96	141	107	135	1050
No-tillage	141	162	172	131	161	97	94	958
Total	520	468	586	340	523	328	417	3182

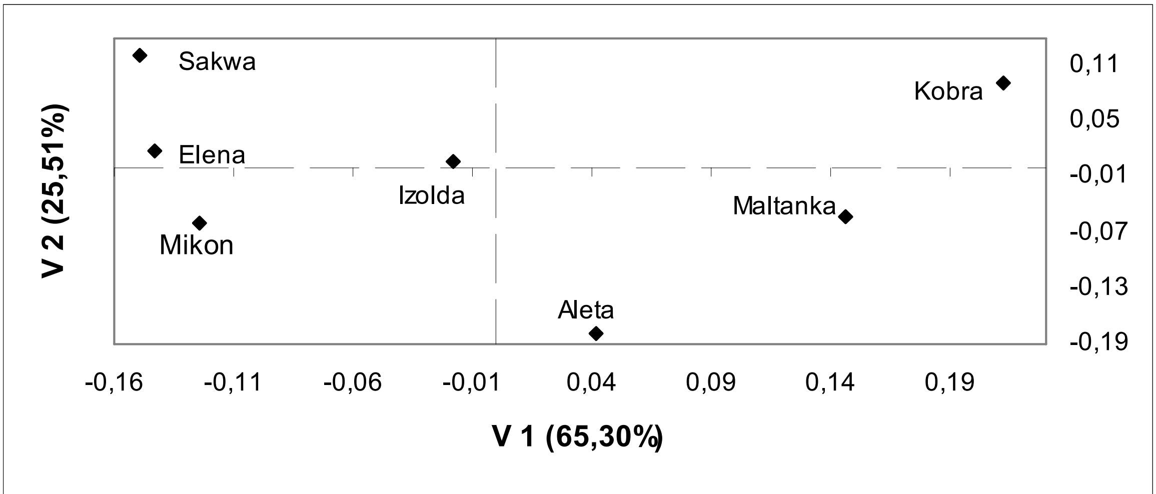

Fig. 1 Variability of susceptibility of particular winter wheat cultivars to *F. avenaceum* infection on the culm base (standardization of row and column profiles) in relation to forecrop type, tillage systems and plant growing season

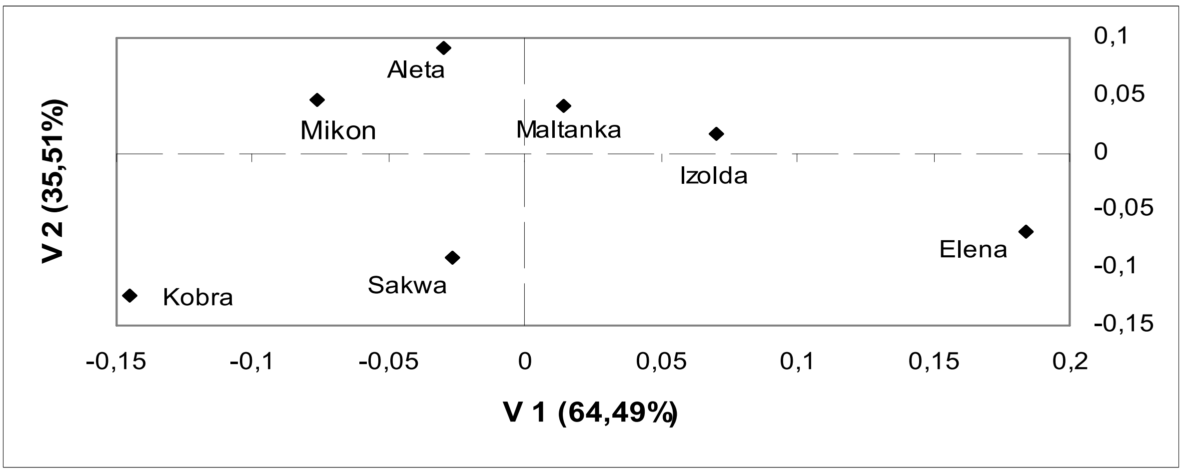

Fig. 2 Variability of susceptibility of particular cultivars of wheat to infection with *F. culmorum* on the culm base (standardization of row and column profiles) as dependent on forecrop type, tillage systems and plant growing season

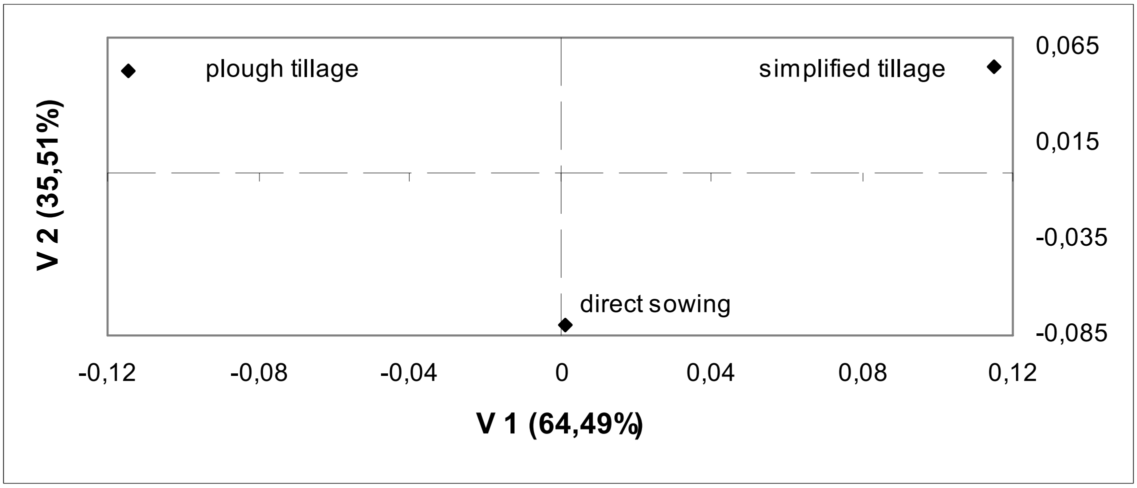

Fig. 3 Variability of tillage systems - infection with *F. culmorum* on the culm base (standardization of row and column profiles) as dependent on particular cultivars of wheat and plant growing season

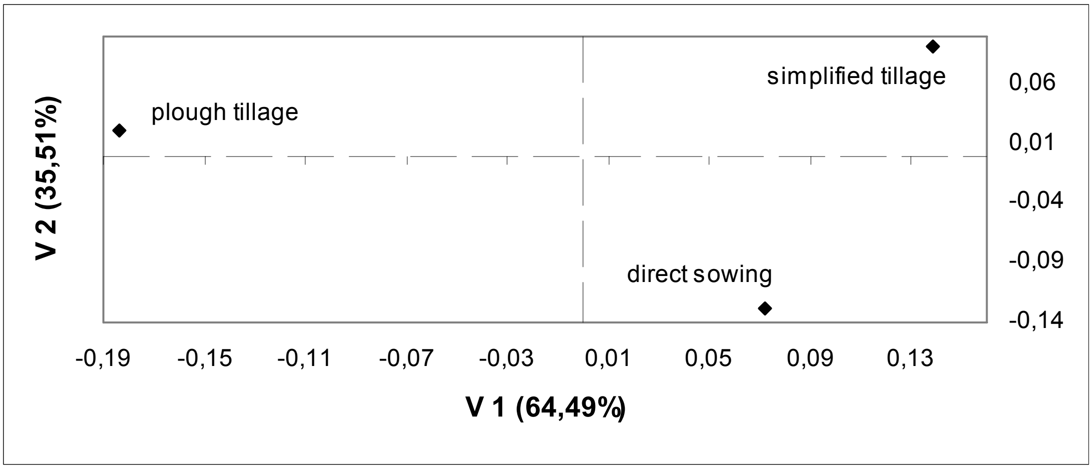

Fig. 4 Variability of tillage systems - infection with *F. avenaceum* on the culm base (standardization of row and column profiles) in dependence on particular cultivars of wheat and plant growing season

DISCUSSION

The results obtained prove that weather conditions do significantly affect the intensity of occurrence of *F. avenaceum* and *F. culmorum* on wheat. The frequent occurrence of the above-mentioned fungi in Poland is also reported by other authors (Goliński et al. 2002; Kiecana et al. 2006), while the climatic conditions in Bavaria – Germany, Ireland or Great Britain favour the spread of *F. poae* (Xu et al. 2005; Büttner, 2006). The culm-base parts of wheat cultivars were infected mainly by *F. culmorum* and *F. avenaceum,* whereas *F. poae*, *F. graminearum* and *F. equiseti* were found occasionally. *Fusarium culmorum* is characterized by relatively small competitiveness, which can explain increased infection of wheat in 2001/2002. September and October 2001 featured steady temperature and relatively low precipitation. Such conditions were advantageous for wheat infection with *F. culmorum*. In 2003 high precipitation was recorded during the growing period, which promoted the infection with *F. avenaceum.* The occasional occurrence of *F. graminearum* enabled the development of *F. avenaceum* and *F. culmorum*. It is noteworthy that *F. graminearum* is relatively aggressive and occurs predominantly in corn crops in Germany (Schlüter et al. 2006). The differences in the numbers of *Fusarium* fungi may be explained by the conservative effect of plough tillage (Köller and Linke, 2001). Ascospores of *F. graminearum and F. avenaceum,* formed on after – harvest residues, can be transported by wind over large distances. The infection with *F. avenaceum* can be considerably reduced by the application of conventional plough tillage, which inhibits spores of the fungi. However, such measures will not be effective in the case of predominance of *F. culmorum*. Fungal chlamydospores formed in crop residues, buried by ploughing under a 20-25 cm layer of soil, can survive better in such conditions than on the soil surface. Subsequent ploughing brings the pathogens onto the surface, where they meet optimum conditions for infecting grain (Schlüter et al. 2006). The application of simplified tillage methods, consisting in mixing harvest residues with the upper layer of soil, promotes the growth of antagonistic fungi, bacteria and microbes that decompose straw, which in turn results in a significant reduction in the numerical force of *F. culmorum* compared to typical plough tillage. Unfortunately, without professional support by a phytopathologist, farmers could not be able to put this knowledge into practice. This is the reason why in Poland, under the current climatic conditions and with typical crop rotation, we recommend energy-saving, long-lasting simplified tillage which prevents the occurrence of many fungal diseases.

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Wpływ sposobu uprawy roli i rodzaju przedplonu na częstotliwość występowania *Fusarium culmorum* i *F. avenaceum* u podstaw źdźbła wybranych odmian pszenicy ozimej

Streszczenie

W latach 2001 – 2003 analizowano zależności pomiędzy liczebnością *Fusarium culmorum* i *F. avenaceum,* grzybów występujących u podstawy źdźbła, siedmiu odmian pszenicy ozimej i rodzajem przedplonu oraz systemem uprawy. Badania przeprowadzono w Polsce, na poletkach z lekką glebą w dolnośląskiej stacji doświadczalnej należącej do Instytutu Uprawy Nawożenia i Gleboznawstwa w Puławach (IUNG). Analiza logarytmiczno-liniowa i korespondencji dowiodła zróżnicowanej odporności poszczególnych odmian pszenicy na grzyby *F. culmorum*

i *F. avenaceum*. Zaobserwowano również znaczne różnice w fuzariozach pszenicy w zależności od wielkości opadów atmosferycznych i temperatury w trakcie sezonu wegetacyjnego roślin. Odmiana Kobra była wysoce odporna na *F. avenaceum*. Najmniejsze ilości grzybów *F. culmorum* stwierdzono u podstawy źdźbła odmiany Izolda. Uprawa kukurydzy jako przedplonu owsa i pszenicy jarej w znacznym stopniu różnicowała występowanie gatunków grzybów w badanych systemach uprawy. W uprawie płużnej pszenica była porażona głównie przez *Fusarium culmorum,* podczas gdy w przypadku siewu bezpośredniego poszczególne odmiany pszenicy były w większości porażone przez *F. avenaceum.*