JOURNAL OF PLANT PROTECTION RESEARCH
Vol. 45, No. 1 (2005)

INFLUENCE OF PLANT PROTECTION PRODUCTS ON THE DECREASE OF *FUSARIUM* FOOT-ROT (*FUSARIUM* SPP.) OF WINTER WHEAT

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Accepted: February 10, 2005

Abstract: The incidence of fusarium foot-rot occurrence on the winter wheat cultivars Roma and Sakwa was examined in the years 2001–2003. Strict plot experiments were set up by the method of random sub-blocks in Tomaszkowo near Olsztyn. Fungicides were applied on the growing plants during the periods of shooting and heading. The control plots were sprayed with water. The sanitary state of leaf sheaths was evaluated at heading phase (GS 55). The symptoms of fusarium foot-rot were examined at the phase of milky maturity (GS 75) and waxy maturity of grain (GS 87). The study aimed at assessing the average index of infection of the winter wheat stem base caused by the species of *Fusarium* genus, assessing the vulnerability of the Roma and Sakwa cultivars to these fungi and determining the effectiveness of pesticides in control of fusarium foot-rot.
Fusarium foot-rot (*Fusarium* spp.) of winter wheat dominated on the winter wheat stem base. Most of the examined stems were severely infected. The Roma cultivar was more susceptible to infection by *Fusarium* fungi than the Sakwa cultivar. The effectiveness of fungicides in controlling fusarium foot-rot on the winter wheat was satisfactory, but largely depended on the cultivar and weather conditions. Mirage 450EC and Sportak Alpha 380EC fungicides were the most effective. The species *F. culmorum* and *F. avenaceum* dominated in the fungal populations colonizing the stem base of winter wheat with visible symptoms typical of fusarium foot-rot.

Key words: foot-rot, winter wheat, fungicide

INTRODUCTION

Fusarium foot-rot (*Fusarium* spp.) is one of the most serious diseases of winter wheat stem base in Poland. Recently, its increasing occurrence has been observed during the period of winter wheat ripening, particularly if the share of this cereal in crop rotation is high. The fungi of the *Fusarium* genus are present on growing cereals

throughout their vegetation period and can cause a considerable yield reduction (Jańczak 1990; Kurowski and Majchrzak 2000).

Fusarium foot-rot is caused by *Fusarium* spp. fungi, primarily *F. culmorum* (W.G. Smith) Sacc., *F. avenaceum* (Corda ex Fr.) Sacc., *F. nivale* (Fr.) Ces. (*Microdochium nivale* Samuels et Hallet) and *F. graminearum* Schwabe (Colbach et al. 1996; Pettitt et al. 1996; Smagacz 1998). Soil, weather conditions and crop rotation affect the occurrence of *Fusarium* spp. (Jaczewska-Kalicka 2000; Kurowski 2002; Pettitt et al. 1996).

The ubiquity of *Fusarium* spp. fungi results from their ability to survive on the debris in soil (*Fusarium* spp. can last in the form of mycelium or chlamydospores for several months) with the capability to grow across a wide temperature range, their competitiveness in relation to other pathogens and their rapid growth and abundant spore production (Pokacka 1991). The infection of plants by these pathogens results in pre- and post-germinating seedling blight, fusarium foot-rot, root-rot and fusarium head blight (Mikołajska et al. 1996b; Parry et al. 1995). *Fusarium* fungi cause loss of seedlings and plants at later stages, worse winter survival, poorer heading and earlier cereal dying out (Mikołajska et al. 1996a). The plants whose root system was damaged by the fungi produce few spikes in heads; also, the spikes are filled with poorly formed grain, with low content of such amino-acids as prolamine and glutine (Łacicowa 1979).

It seems that in order to take advantage of the high yielding potential of cereals in a simplified crop rotation, cultivars which are more resistant to *Fusarium* fungi should be mostly grown and pesticide applications are recommended during the vegetation period (Jańczak and Pokacka 1994; Kaniuczak 2000).

This study aimed at evaluating the mean index of infection of the winter wheat stem base by *Fusarium* spp., examining the susceptibility of the Roma and Sakwa cultivars to infection by these fungi and the effectiveness of plant protection products in control of fusarium foot-rot in winter wheat crop.

MATERIALS AND METHODS

The study was conducted in the years 2001–2003 in a plot experiment, set up by the method of random sub-blocks in four replications, on 8.75 square meter plots. Experiments were located at the Teaching and Research Department in Tomaszków near Olsztyn. The study was conducted on a brown soil. Agrotechnological procedures were performed throughout the experimental area according to the standards and recommendations.

Roma and Sakwa winter wheat cultivars were included in a conducted investigation. The first spraying of plants was performed at the beginning of the shooting phase (GS 30), with: Bion 50 WG, Karben 500 SC, Mirage 450 EC or Alert 375 SC. At the heading phase (GS 55) Amistar 250 SC, Bravo 500 SC, Sportak Alpha 380 WP or Penncozeb 80 WP were applied. The control plots were sprayed with water at the same time. Plant protection products were applied at the doses and dates recommended by the Institute of Plant Protection for winter wheat. The main characteristics of the products used in the study are presented in Table 1.

The occurrence of disease symptoms on leaf sheaths was evaluated at the heading phase (GS 55) and that on the stem base at the phase of milky maturity (GS 75) and

Table 1. Characteristics of products included in the study

Active ingredients	Trade name	Mode action
125 g fusilazol	Alert 375 SC	Sterol biosynthesis inhibitor
250 g carbendazim		Inhibitor of fungal cells dividing
250 g azoxystrobin	Amistar 250 SC	Respiration inhibitor
50 g acybenzolar -S- methyl	Bion 50 WG	Plant resistance stimulator
500 g chlorothalonil	Bravo 500 SC	Respiration inhibitor
500 g carbendazim	Karben 500 SC	Inhibitor of fungal cells dividing
450 g prochloraz	Mirage 450 EC	Sterol biosynthesis inhibitor
80 g mancozeb	Penncozeb 80 WP	Respiration inhibitor
300 g prochloraz	Sportak Appha 380 EC	Sterol biosynthesis inhibitor
80 g carbendazim		Inhibitor of fungal cells dividing

waxy maturity of grain (GS 87). At each assessment date, 100 plants were randomly chosen from each plot. In the laboratory, soil was removed from the stems, and if the stem bases were to be evaluated soil was also cleaned out from the leaf sheaths.

The infection of leaf sheaths and stem bases was evaluated using a three-degree scale (Lipps and Herr 1982): 0 – stems without any visible symptoms of the disease; 1 – stems slightly infected (less than half of their surface), 2 – stem bases strongly infected (more than half of their area).

The results were analysed by the analysis of variance of four factors with Duncan's test, at a level of significance of 0.05 (Statistica ver. 6.0, 2001), and presented as the index of infection.

The frequency of occurrence of stems with the symptoms of fusarium foot-rot was also presented by the percentage of plants with the typical symptoms of the disease.

The composition of colonies which inhabited the leaf sheaths of winter wheat with symptoms of fusarium foot-rot was determined during the stage of heading (GS 55) and those at the stem base at the phase of milky maturity (GS 75). The mycological analysis was conducted by the method developed by Reinecke and Fehrmann (1979) and by Rashid and Schlösser (1977). The results were presented as the percentage of fungal species inhabiting the infected stems of winter wheat.

RESULTS

The three-year study showed that fusarium foot-rot (*Fusarium* spp.) was a dominant disease which occurred on winter wheat stems. The fusarium symptoms were recorded on most of the evaluated stems (Fig. 1). The index of fusarium foot-rot infection varied from 0.2 to 0.95 (Table 2). *Fusarium* spp. infected the winter wheat stem base in the early stages of development; initially the fungi attacked leaf sheaths. At these stages the disease intensity was low, but gradually increased and at the stage of milky maturity the mean index of infection reached 0.58. At the stage of waxy maturity the mean index of infection was as high as 0.63 and proved to be only slightly higher than in the second date of observation (Table 2).

The differences in terms of infection of winter wheat stems by *Fusarium* species were visible between cultivars (Fig. 1). At the heading phase, an average of 53.9% of the examined leaf sheaths showed symptoms of fusarium foot-rot. At the same time only 43% of stems of the Sakwa cultivar had the symptoms of the disease. At

the period of waxy maturity of grain, the occurrence of fusarium foot-rot increased as compared to the first observation by 7.8% on average for the first of the cultivars and by 5.1% for the other (Fig. 1). The cultivar Roma was much more strongly infected by *Fusarium* spp. than the cultivar Sakwa (Fig. 2). In the years 2001 and 2003, at the heading period and at the milky and waxy maturity stage, the differences between the index of infection for both cultivars were statistically significant. In 2002, the differences were smaller and statistically insignificant at phases GS 55 and GS 87 (Table 2).

Each product generally reduced the percentage of stems with fusarium foot rot. Only the application of Bion 50 WG and Amistar 250 SC on the Roma cultivar did not protect plants against the disease. In all years of experiments and at all the development stages, the applied products also reduced the intensity of fusarium foot-rot (Table 2, Fig. 2). Generally, the differences between the mean index of infection of stem base of winter wheat which increased on the control plots and those

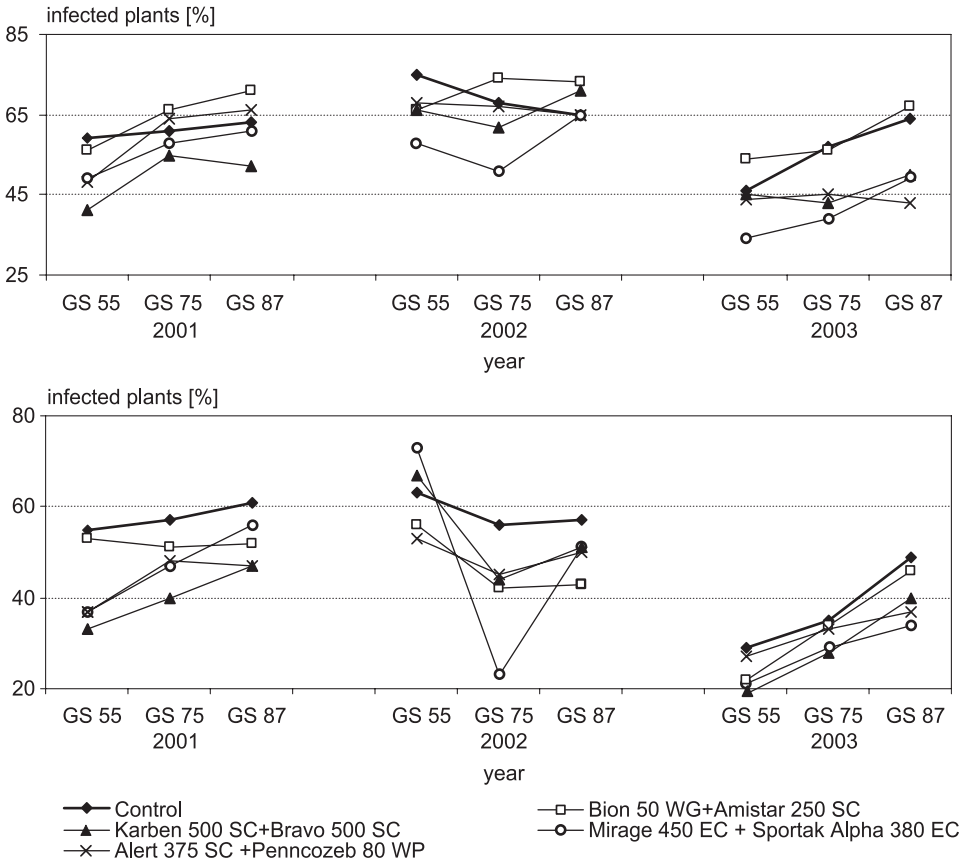

Fig. 1. Occurrence of *Fusarium* foot-rot of winter wheat on cv. Roma (above) and cv. Sakwa (below) controlled chemically

Table 2. Occurrence of Fusarium foot-rot in relation to wheat cultivar and chemical treatments (Tomaszkowo)

Years	Stage	Cultivars	Indices of infection in treatments					Mean
			Control	Bion 50 WG Amistar 250 SC	Karben 500 SC + Bravo 500 SC	Mirage 450 EC +Sportak Alpha 380 EC	Alert 375 SC +Penncozeb 80 WP	
2001	GS 55	Roma	0.77 b+D26	0.65 bc	0.5 cd	0.55 c	0.64 bc	0.62 C
		Sakwa	0.6 c	0.57 c	0.37 d	0.44 cd	0.39 d	0.47 F
	GS 75	Roma	0.79 b	0.8 ab	0.65 bc	0.74 b	0.75 b	0.75 B
		Sakwa	0.63 bc	0.56 c	0.44 cd	0.52 cd	0.5 cd	0.53 DEF
	GS 87	Roma	0.78 b	0.81 ab	0.62 bc	0.74 b	0.77 b	0.74 B
		Sakwa	0.64 bc	0.62 bc	0.48 cd	0.62 bc	0.51 cd	0.57 CDE
2002	GS 55	Roma	0.95 a	0.85 ab	0.81 ab	0.56 c	0.88 a	0.81 AB
		Sakwa	0.87 a	0.6 c	0.81 ab	0.94 a	0.67 bc	0.78 AB
	GS 75	Roma	0.85 ab	0.95 a	0.73 b	0.55 c	0.77 b	0.77 AB
		Sakwa	0.58 c	0.47 cd	0.46 cd	0.23 e	0.5 cd	0.45 FG
	GS 87	Roma	0.84 ab	0.86 ab	0.89 a	0.79 b	0.82 ab	0.84 D
		Sakwa	0.69 bc	0.53 cd	0.54 c	0.55 c	0.54 c	0.57 CDE
	GS 55	Roma	0.59 c	0.62 bc	0.48 cd	0.38 d	0.55 c	0.52 EF
		Sakwa	0.31 de	0.22 e	0.2 e	0.26 e	0.29 de	0.26 H
2003	GS 75	Roma	0.79 b	0.67 bc	0.56 c	0.50 cd	0.57 c	0.62 CD
		Sakwa	0.43 d	0.4 d	0.35 de	0.3 de	0.38 d	0.37 G
	GS 87	Roma	0.76 b	0.73 bc	0.55 c	0.54 c	0.49 cd	0.61 CD
		Sakwa	0.56 c	0.51 cd	0.4 d	0.43 d	0.39 d	0.46 F

Note: means in columns denoted with the same letter do not differ at the 0.05 level of significance (Duncan's multiple range test).

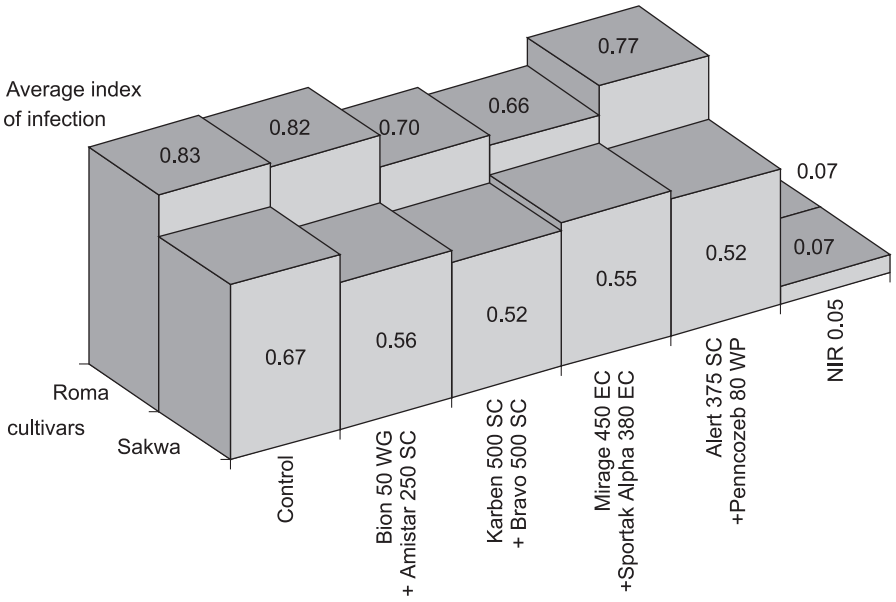

Fig. 2. Effect of the chemical protection on the index of *Fusarium* foot-rot on stem bases

on chemically protected ones proved statistically insignificant. Only in the year 2001 Karben 500 SC and Bravo 500 SC fungicides inhibited the development of fusarium foot-rot; the analysis of variance showed that the differences for that year were statistically significant. At the heading period, the mean index of infection of the stem base of chemically protected plants was dependent upon a cultivar and was 25% and 31% lower than for the control (Fig. 2, Table 2). Apart from that, the development of *Fusarium* fungi on the Sakwa cultivar was inhibited by the following fungicides: Mirage 450 EC and Sportak Alpha 380 EC, and also Alert 375 SC and Penncozeb 80 WP (Fig. 2). The inhibiting effect of fungicides was observed only during the heading phase. At the ripening phase, the differences between the treatments were less distinct. In 2002, at the heading period, statistically significant effect on the development of *Fusarium* fungi was observed for the products Mirage 450 EC and Sportak Alpha 380 EC on the Roma cultivar, and Bion 50 WG and Amistar 250 SC as well as Alert 375 SC and Penncozeb 80 WP on the Sakwa cultivar (Tab. 2). However, only in the case of the first treatment, did the inhibiting action of product persist through the milky maturity phase. The drought in the last year of the study did not favour the development of fusarium foot-rot. During the heading and milky maturity growth stages, the following products were effective in controlling fusarium foot-rot: Karben 500 SC and Bravo 500 SC, Mirage 450 EC and Sportak Alpha 380 EC, as well as Alert 375 SC and Penncozeb 80 WP (Fig. 2).

Fusarium spp. were primarily isolated from the leaf sheaths and stems of winter wheat with the symptoms of fusarium foot-rot (Fig. 3). In the subsequent years of the study, they accounted for 39% to 84% of the total of isolated fungal cultures

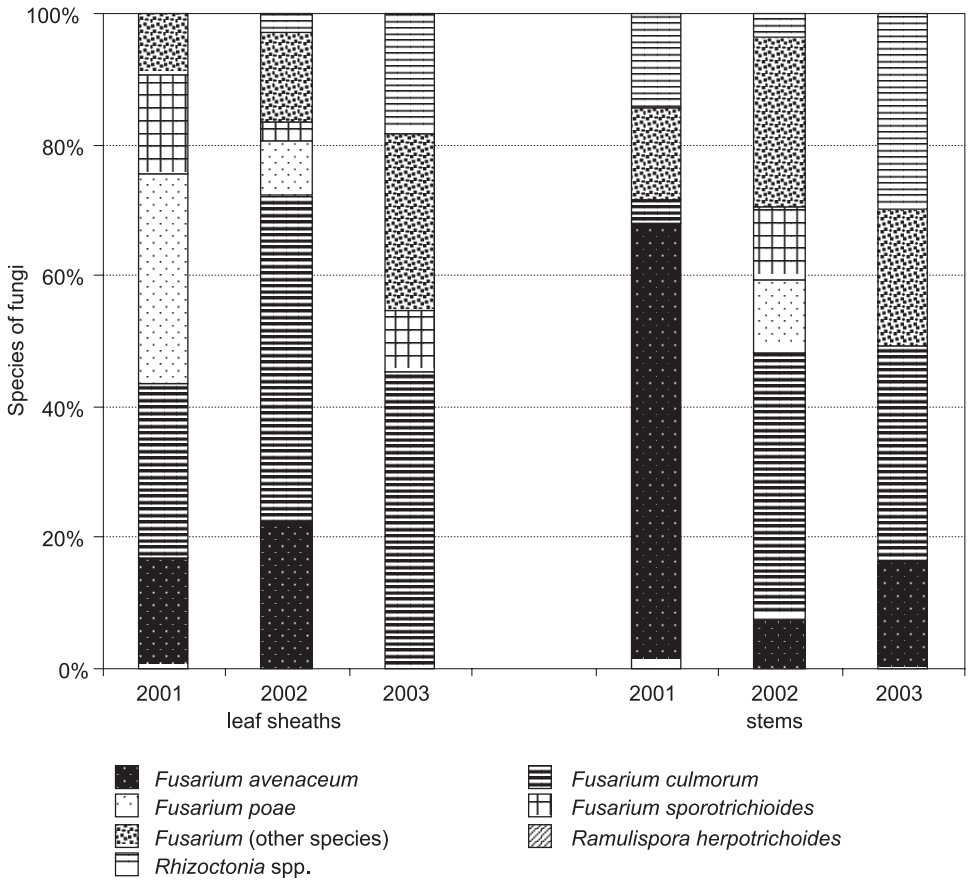

Fig. 3. Fungal species isolated from infected stem base of winter wheat of cultivars Roma and Sakwa

from leaf sheaths and stems. They were identified as *F. avenaceum, F. culmorum, F. graminearum, Microdochium nivale, F. poae, F. sporotrichioides, F. equiseti, F. oxysporum, F. tricinctum*. The species *F. culmorum* dominated in the analysed material. The beginning of the year was particularly favourable to its development. In the subsequent years of study, as much as 22%, 26% and 21% of the colonies of fungi obtained from leaf sheaths belonged to this species. The fungus *F. avenaceum* played a significant role in causing the symptoms of fusarium foot-rot. This species accounted for 6% to 33% of the total isolates, depending on the treatment. Its occurrence depended on weather conditions during the vegetation period. In 2001, it dominated on stems and in 2003 was not found on leaf sheaths.

The species *M. nivale* and *F. graminearum* were only sporadically isolated from stem bases. The fungus *M. nivale* was isolated only from the winter wheat stem bases. Four colonies were obtained in 2002 and one in 2003. *F. graminearum* was isolated in 2002 from leaf sheaths and from stems (Fig. 3).

DISCUSSION

This study has shown that in the province of Warmia and Mazury the foot-rot diseases occur frequently, however, they varied in intensity. The index of infection, found in this study, was similar to that recorded by Kurowski (2002). In this study, the symptoms of fusarium foot-rot (*Fusarium* spp.) were observed more frequently than those of other stem base diseases. The obtained results show increasing importance of fusarium foot-rot in the area of Warmia and Mazury. Similar findings were also revealed by Kurowski (2002). An increase in the intensity of this disease in other parts of Poland has been reported by Burgieł (1996), Jaczewska-Kalicka (2000) and Łacicowa et al. (1985). This is probably due to high tolerance of the pathogens of genus *Fusarium* to unfavourable weather conditions (Remlein 1996). In numerous reports (Bojarczuk et al. 1991; Hudec et al. 2000; Parry 1990) the *Fusarium* fungi have been considered to be the main cause of blights throughout the whole vegetation period.

Significant differences in the intensity of fusarium foot-rot in consecutive years of study imply the existence of various factors, which affect their occurrence. Polley and Turner (1995) claim that different species of genus *Fusarium* have different requirements in terms of the weather conditions; consequently, various species may dominate in successive years. The year 2003 was particularly unfavourable to the development of fusarium foot-rot at the initial stage of plant development. Its main features were high temperatures and scarce rainfall. A considerable decrease of the intensity of fusarium foot-rot of winter wheat was observed, which was consistent with earlier reports (Kurowski et al. 1992).

Although as a result of breeding efforts new cultivars are being produced all the time with increased resistance to the pathogens from the *Fusarium* genus, no cultivar exists which is resistant to all the pathogen agents that cause the foot and root-rot. In the course of the study, differences were recorded between the index of infection of different cultivars of winter wheat. The Sakwa cultivar showed less vulnerability to infection by the pathogens of *Fusarium* genus than the Roma cultivar. In the study on the susceptibility of cultivars to fusarium foot-rot, Kubiak and Korbas (1999) included the Roma cultivar to the group of cultivars susceptible to *Fusarium* infection.

The effectiveness of the examined products in controlling fusarium foot-rot was limited and clearly depended on the weather conditions. As in the study conducted in the southern Poland (Nadolnik and Dłużniewska 1997), plant protection products restricted the spread of *Fusarium* fungi; however, this effect was frequently statistically insignificant. At the beginning of the heading phase, fungicides frequently inhibit the development of fusarium foot-rot. However, the differences between the mean index of infection by *Fusarium* fungi between the control objects and those treated with fungicides, became less distinct. This probably resulted from the fact that the fungi of the genus *Fusarium* intensely attacked plants throughout the period of vegetation (Łacicowa et al. 1979; Polley and Turner 1995). Consequently, the effectiveness of the fungicides in controlling fusarium foot-rot, in the same way as in the study by Pietryga and Drzewiecki (2000) was much lower than in controlling *Ramulispora herpotrichoides* (unpublished data).

The species of the genus *Fusarium* dominated in all the analysed colonies of fungi which inhabited leaf sheaths and stems of the winter wheat with the symptoms of fusarium foot-rot. These species are considered the main ones which colonize cereal stems and infect plants throughout the vegetation period (Kurowski et al. 1990; Łacicowa et al. 1985; Majchrzak 1985; Mikołajska et. al 1996a). The study shows high sharing of the species *F. avenaceum* and *F. culmorum*. Earlier research suggests that these species should be counted among the most serious to cereals grown in northern Poland (Kurowski and Majchrzak 2000; Majchrzak and Mikołajska 1982).

F. culmorum is a particularly serious pathogen of the roots and stem base of wheat (Łacicowa 1979). Mesterhàzy (1977) found *F. culmorum* to be the primary colonizer and claimed it to be the sole cause of stem base necrosis in Triticale in Hungary. The ability of *F. culmorum* to infect cereals with great intensity results from the fact that it produces phytotoxic metabolites. They cause plants to take up excessive amounts of phosphorus, inhibit the germinating process, the growth of roots and production of capillary roots (Łacicowa 1987). Pathogenicity of *F. avenaceum* in relation to cereals is weaker than that found in *F. culmorum* and *F. graminearum*, but its mass occurrence can cause considerable infection and great loss. The least pathogenic isolates of *F. culmorum* are more serious than the most pathogenic ones of *F. avenaceum*.

Microdochium nivale is considered the main cause of snow mould. The pathogen damages germs, attacks roots, deforms seedlings and restricts their growth, and intensely infects winter cereals, which grow under snow in early spring and which are weakened by winter period (Bojarczuk and Bojarczuk 1979). It seems that this pathogen attacks only sporadically plants in later development stages. The species *F. graminearum* also first attacks roots, germs and leaf sheaths of young seedlings, making them wilt partly or totally. In later development stages it infects the tillering nodes and stem base, producing the symptoms of root-rot (Bojarczuk and Bojarczuk 1979); this is, however, considerably less important in the region of Warmia and Mazury (Kurowski 2002).

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POLISH SUMMARY

WPŁYW ŚRODKÓW OCHRONY ROŚLIN NA OGRANICZENIE WYSTĘPOWANIA FUZARYJNEJ ZGORZELI PODSTAWY ŹDŹBŁA (*FUSARIUM* SPP.) PSZENICY OZIMEJ

W latach 2001–2003 analizowano występowanie fuzaryjnej zgorzeli podstawy źdźbła pszenicy ozimej odmian Roma i Sakwa. Ścisłe doświadczenie poletkowe założono metodą losowanych podbloków, w czterech powtórzeniach, w Tomaszkowie koło Olsztyna. W okresie strzelania w źdźbło i w okresie kłoszenia wykonano zabieg ochronny środkami ochrony roślin. Kontrolę stanowiły poletka opryskiwane wodą. W fazie kłoszenia (GS 55) oceniono zdrowotność pochew liściowych, a w fazie dojrzałości mlecznej (GS 75) i dojrzałości woskowej ziarna (GS 87) podstaw źdźbeł. Analizowano także skład zbiorowisk grzybów zasiedlających pochwy liściowe oraz podstawy źdźbeł pszenicy ozimej wykazujące objawy fuzaryjnej zgorzeli podstawy. Celem prezentowanych badań było poznanie indeksu porażenia podstawy źdźbła pszenicy ozimej przez gatunki z rodzaju *Fusarium,* zbadanie podatności odmian Roma i Sakwa na infekcje przez te grzyby oraz określenie skuteczności środków ochrony roślin w ograniczeniu rozwoju fuzaryjnej zgorzeli podstawy źdźbła pszenicy ozimej.

Na podstawie źdźbła pszenicy ozimej dominowała fuzaryjna zgorzel podstawy źdźbeł (*Fusarium* spp.). Większość ocenianych źdźbeł porażona była w stopniu silnym. Odmiana Roma była bardziej wrażliwa na porażenie przez grzyby z rodzaju *Fusarium* niż odmiana Sakwa. Skuteczność środków ochrony roślin w zwalczaniu fuzaryjnej zgorzeli podstawy źdźbła była zadawalająca, lecz w dużej mierze uzależniona od odmiany i przebiegu warunków pogodowych. Największą skuteczność wykazywały fungicydy Mirage 450 EC i Sportak Alpha 380 EC. Gatunki *F. culmorum* oraz *F. avenaceum* dominowały w zbiorowiskach grzybów zasiedlających podstawy źdźbła pszenicy ozimej wykazującej objawy fuzaryjnej zgorzeli podstawy źdźbła.