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FUNGAL DISEASES ON ROOTS AND STEM BASES OF SPRING RYE CULTIVATED IN PURE STAND OR IN MIXTURES WITH OTHER CROPS

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Abstract

Health status of spring rye cultivated in pure stand and in mixtures with oats, yellow lupine and blue lupine was compared. Eyespot and root rot diseases of rye occurred with the highest intensity. Rye cultivation in mixtures influenced only the variation of root and stem base infestation with *Fusarium* spp. Rye was infected in lowest degree when grown in mixtures, especially with lupines. Pathogenic fungi occurring on rye roots were mostly represented by *Gaeumannomyces graminis* var. *tritici* and *Fusarium* spp. Stem bases were also infected by *Fusarium* spp., especially *F. culmorum*, *F. equiseti* and *F. avenaceum*. Cultivation of rye in mixtures did not affect composition of fungal species occurring on roots and stem bases.

Key words: spring rye, diseases, roots, stem base, mixture sowing, oats, yellow lupine, blue lupine, fungi

Introduction

High share of cereals in crop rotation results in considerably worse health status and lower yield. There are efforts to reduce negative effects of such situation by cultivation of various crop mixtures (Rudnicki and Wasilewski 2000). Spring cereals grown in cereal mixtures, as well as in cereal-leguminous mixtures, are often less threatened by fungi pathogenic to leaves and sometimes roots and stem bases (Vilich-Meller 1992). These mixtures positively effect health of cereals grown after them (Vilich 1993, Lemańczyk and Sadowski 2002).

Till now, oats has been considered a phytosanitary crop in rotation with high share of cereals. Spring form of rye is also potentially useful in such rotations, but there are no clear results of research on phytosanitary value of this crop

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(Grochowski et al. 1996, Galek 2003). It can be used as an ingredient of mixtures with other cereals or leguminous plants (Burczyk 1958). Akemo et al. (2000) reported that spring sown rye cultivated in mixture with pea significantly reduced weediness as compared with pure stand.

The aim of the present study was evaluation of roots and stem base health status of spring rye cultivated in pure stand and inter-species mixtures.

Materials and methods

The research was carried out over 2000–2002 on experimental fields at the Mochełek Experimental Station (17°51'E, 53°13'N), University of Technology and Life Sciences in Bydgoszcz. Weather conditions in the years are presented in Table 1. The experiment was set up as a randomised block design with three replications, on a podzolic soil classified as good for rye cultivation. The research included spring rye cv. 'Abago' grown in pure stand and in mixtures: rye with oats, rye with yellow lupine and rye with blue lupine, sown in the following rates:

1 – spring rye in pure stand – 500 plants per 1 m^2,
2 – spring rye with oats – 300 + 300 plants per 1 m^2,
3 – spring rye with yellow lupine – 300 + 75 plants per 1 m^2,
4 – spring rye with blue lupine – 300 + 75 plants per 1 m^2.

Table 1

Mean monthly temperature and rainfall at Mochełek Experimental Station

Month	Temperature (°C)				Rainfall (mm)			
	2000	2001	2002	mean*	2000	2001	2002	mean*
March	3.1	1.1	3.7	1.9	36.1	55.9	38.2	24.3
April	11.0	7.0	7.5	7.3	14.6	42.4	17.7	28.0
May	14.5	13.1	15.7	12.8	24.6	34.9	111.5	41.7
June	16.7	14.3	16.3	16.7	19.1	80.5	31.3	53.4
July	15.7	19.3	18.0	20.6	100.9	146.1	77.9	70.8
August	17.3	18.3	19.9	17.4	58.9	49.7	58.0	52.0

*Mean value for 1949–2008.

Observations of root and stem base health status were carried out at shooting stage (GS 34–36; Zadoks et al. 1974) and milk maturity stage (GS 75–77). The root health status was evaluated using a 0–4° scale. Stem base infections with *Fusarium* spp., *Oculimacula* spp. (eyespot) and *Rhizoctonia cerealis* (sharp eyespot) were assessed using a 0–3° scale. At each sampling time the health status of randomly collected 30 plants from each replication was analysed. For statistical purpose degrees of infection were transformed into "disease index" (DI) according to Townsend and Heuberger's formula (Wenzel 1948). Tukey's test was used for evaluation of significance differences.

The macroscopic evaluation of disease symptoms was accompanied by isolation of fungal species from roots and stem base and their identification. For each combination 100 fragments from infected roots and 100 from stem bases were sampled. Detailed data on macroscopic evaluation of the health status and isolation of fungi were described by Lemańczyk and Sadowski (2002).

Results

Take-all infection rate on spring rye roots was relatively high and varied in particular years. In 2002 DI was the highest (up to 42.5%), and in 2000 and 2001 its value was significantly lower and similar in both years (Table 2). Mean DI at shooting stage calculated for three years was 13.9%, while at milk maturity stage 24.6%. Significant effect of companion crops on root health was observed only at shooting stage. At this development stage rye cultivated in mixture with lupines, especially blue lupine had the lowest take-all DI.

Table 2

Take-all disease index of spring rye roots in two growth stages (%)

Sowing combination	Shooting stage				Milk maturity stage			
	2000	2001	2002	mean	2000	2001	2002	mean
Spring rye in pure stand	12.7 a	10.8 b	26.9 b	16.8 c	21.7 a	19.3 a	42.5 a	27.8 a
Spring rye + oats	9.7 a	9.4 ab	23.7 ab	14.3 b	20.3 a	20.7 a	33.5 a	24.8 a
Spring rye + yellow lupine	11.3 a	5.8 a	23.1 ab	13.4 ab	19.0 a	13.0 a	29.3 a	20.4 a
Spring rye + blue lupine	10.7 a	7.5 ab	15.6 a	11.3 a	18.7 a	21.3 a	35.8 a	25.3 a
Mean	11.1	8.4	22.3	13.9	19.9	18.6	35.3	24.6

Values in columns followed by the same letter are not significantly different.

Stem base health status was differentiated, with considerable impact of eyespot. The highest *Oculimacula* spp. infection rate of spring rye stem was noted in 2002 (DI = 53.1%) in the mixture of rye with blue lupine (Table 3). Yet, the difference in symptom intensity between pure stand and mixtures was not significant.

Table 3

Occurrence of eyespot (*Oculimacula* spp.) in two growth stages – DI (%)

Sowing combination	Shooting stage				Milk maturity stage			
	2000	2001	2002	mean	2000	2001	2002	mean
Spring rye in pure stand	1.7	8.6	39.2	16.5	15.3	24.7	44.7	28.2
Spring rye + oats	0.3	7.5	34.7	14.2	15.2	24.3	43.4	27.6
Spring rye + yellow lupine	0.7	7.8	38.1	15.5	14.2	23.0	47.9	28.4
Spring rye + blue lupine	0.7	5.6	35.6	13.9	14.7	25.3	53.1	31.0
Mean	0.8	7.4	36.9	15.0	14.8	24.3	47.3	28.8

Fusarium spp. infestation was considerably lower in all the experimental years (Table 4). Rye grown in mixtures was less affected as compared with pure stand. At the shooting stage rye was least affected when grown with yellow lupine. Considerably higher infection rate occurred in rye grown with blue lupine, and the highest – in pure stand. At the milk maturity stage all the companion crops significantly reduced the infestation of rye stems by *Fusarium* spp., as compared to rye pure stand.

Table 4

Occurrence of Fusarium foot rot in two growth stages – DI (%)

Sowing combination	Shooting stage				Milk maturity stage			
	2000	2001	2002	mean	2000	2001	2002	mean
Spring rye in pure stand	10.0 b	3.1 b	2.5 a	5.2 c	14.7 b	9.0 a	12.2 a	12.0 b
Spring rye + oats	6.0 a	1.9 a	5.1 a	4.3 bc	10.3 a	5.3 a	10.8 a	8.8 a
Spring rye + yellow lupine	5.3 a	1.7 a	1.4 a	2.8 a	9.7 a	9.7 a	6.7 a	8.7 a
Spring rye + blue lupine	7.7 ab	1.9 a	2.4 a	4.0 b	11.3 a	9.3 a	6.9 a	9.2 a
Mean	7.3	2.2	2.8	4.1	11.5	8.3	9.2	9.7

Values in columns followed by the same letter are not significantly different.

Table 5

Occurrence of sharp eyespot (*Rhizoctonia cerealis*) on spring rye cultivated in pure stand or mixtures – DI (%)

Sowing combination	Shooting stage				Milk maturity stage			
	2000	2001	2002	mean	2000	2001	2002	mean
Spring rye in pure stand	0.0	0.3	0.3	0.2	0.0	1.1	0.8	0.6
Spring rye + oats	0.3	0.3	0.0	0.2	0.0	0.3	0.6	0.3
Spring rye + yellow lupine	0.0	0.0	0.3	0.1	0.3	0.0	0.3	0.2
Spring rye + blue lupine	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.1
Mean	0.1	0.2	0.2	0.2	0.1	0.4	0.5	0.3

Rye infestation with *R. cerealis* occurred sporadically and did not depend on pure stand or mixture (Table 5).

Among fungi occurring on the diseased roots of spring rye *Gaeumannomyces graminis* and *Fusarium* spp. (especially *F. culmorum, F. solani, F. equiseti* and *F. avenaceum*) were isolated most frequently (Table 6). Particularly high share of *Fusarium* spp. was obtained in 2000 and *G. graminis* in 2002. *Aureobasidium bolleyi, Bipolaris sorokiniana* and *Rhizoctonia solani* were also isolated among fungi potentially pathogenic to cereals. There was no important variation in species composition of fungi isolated from particular combinations. Most likely the companion crops did not differentiate significantly the composition of rye root pathogens in soil.

Fusarium spp., especially *F. culmorum, F. equiseti* and *F. avenaceum,* were also isolated with the highest frequency from diseased rye stem bases. In 2000 *F. culmorum,*

Table 6

The share of fungi isolated from roots of spring rye cultivated in pure stand or mixtures at the shooting stage (%)

Fungus	Spring rye in pure stand				Spring rye + oats				Spring rye + yellow lupine				Spring rye + blue lupine				Mean
	2000	2001	2002	mean	2000	2001	2002	mean	2000	2001	2002	mean	2000	2001	2002	mean	
Alternaria alternata	–	2.1	–	0.7	–	5.9	–	2.0	–	–	–	–	–	–	–	–	0.7
Aspergillus niger	2.6	–	–	0.9	–	–	–	–	–	6.7	–	2.2	–	11.5	–	3.8	1.7
Aureobasidium bolleyi	5.3	8.3	–	4.5	–	25.5	4.3	9.9	2.1	6.7	3.0	3.9	2.9	7.7	–	3.5	5.5
Bipolaris sorokiniana	–	–	–	–	–	–	–	–	–	1.7	–	0.6	10.0	–	–	3.3	1.0
Chaetomium spp.	5.3	10.4	2.9	6.2	–	–	–	–	–	6.7	1.5	2.7	2.9	13.5	–	5.4	3.6
Cladosporium herbarum	–	–	1.5	0.5	–	–	1.1	0.4	–	–	1.5	0.5	2.9	–	1.6	1.5	0.7
Coniothyrium fuckelii	–	–	–	–	–	–	–	–	–	–	–	–	2.9	–	–	1.0	0.2
Epicoccum nigrum	–	–	–	–	–	–	–	–	–	3.3	–	1.1	–	–	–	–	0.3
Epicoccum purpurascens	–	–	–	–	–	–	1.1	0.4	–	–	–	–	–	–	–	–	0.1
Fusarium avenaceum	–	2.1	10.3	4.1	–	–	–	–	4.1	5.0	7.6	5.6	–	–	17.2	5.7	3.9
Fusarium culmorum	14.5	16.7	–	10.4	27.4	–	–	9.1	21.6	–	1.5	7.7	20.0	3.8	–	7.9	8.8
Fusarium equiseti	14.5	2.1	–	5.5	15.5	–	–	5.2	23.7	6.7	1.5	10.6	–	–	3.1	1.0	5.6
Fusarium oxysporum	7.9	–	–	2.6	8.3	2.0	–	3.4	–	–	–	–	4.3	–	–	1.4	1.9
Fusarium poae	5.3	–	–	1.8	–	–	–	–	–	–	–	–	4.3	–	–	1.4	0.8
Fusarium solani	11.8	4.2	–	5.3	2.4	7.8	3.2	4.5	19.6	13.3	3.0	12.0	7.1	–	–	2.4	6.0
Fusarium total	53.9	25.0	10.3	29.7	53.6	9.8	3.2	22.2	69.1	25.0	13.6	35.9	35.7	3.8	20.3	20.0	27.0
Gaeumannomyces graminis	6.6	16.7	38.2	20.5	9.5	25.5	40.9	25.3	7.2	20.0	42.4	23.2	8.6	17.3	29.7	18.5	21.9
Gliocladium catenulatum	–	–	–	–	4.8	–	–	1.6	–	–	–	–	5.7	–	–	1.9	0.9
Gliomastix murorum	–	–	–	–	–	–	–	–	–	–	–	–	–	1.9	–	0.6	0.2
Gymnoascus reesii	–	–	–	–	–	11.8	–	3.9	–	1.7	–	0.6	–	3.8	1.6	1.8	1.6
Melanospora lagenaria	–	6.3	–	2.1	–	2.0	–	0.7	–	–	–	–	–	–	–	–	0.7
Monocillium indicum	–	2.1	–	0.7	–	–	–	–	–	–	–	–	–	–	–	–	0.2
Mucor spp.	–	8.3	–	2.8	7.1	–	1.1	2.7	–	3.3	–	1.1	2.9	–	4.7	2.5	2.3

Table 6 – cont.

Fungus	Spring rye in pure stand				Spring rye + oats				Spring rye + yellow lupine				Spring rye + blue lupine				Mean
	2000	2001	2002	mean	2000	2001	2002	mean	2000	2001	2002	mean	2000	2001	2002	mean	
Myrothecium verrucaria	–	–	–	–	–	–	–	–	–	–	–	–	–	5.8	–	1.9	0.5
Paecilomyces lilacinus	10.5	–	–	3.5	4.8	–	–	1.6	8.2	–	–	2.7	5.7	–	–	1.9	2.4
Penicillium spp.	7.9	18.8	4.4	10.4	2.4	3.9	15.1	7.1	2.1	16.7	1.5	6.7	–	19.2	3.1	7.5	7.9
Periconia macrospinosa	–	–	4.4	1.5	7.1	2.0	10.8	6.6	4.1	–	–	1.4	14.3	–	4.7	6.3	3.9
Phoma sp.	5.3	–	14.7	6.7	10.7	–	10.8	7.2	7.2	–	15.2	7.5	5.7	–	6.3	4.0	6.3
Pythium sp.	–	–	–	–	–	–	1.1	0.4	–	–	–	–	–	–	–	–	0.1
Rhizoctonia solani	–	2.1	–	0.7	–	3.9	–	1.3	–	–	–	–	–	–	–	–	0.5
Scopulariopsis brevicaulis	–	–	–	–	–	3.9	–	1.3	–	–	–	–	–	–	–	–	0.3
Trichoderma koningii	–	–	–	–	–	–	–	–	–	3.3	1.5	1.6	–	–	–	–	0.4
Trichoderma polysporum	–	–	–	–	–	2.0	–	0.7	–	1.7	–	0.6	–	1.9	–	0.6	0.5
Trichoderma viride	2.6	–	4.4	2.3	–	–	–	–	–	1.7	–	0.6	–	11.5	3.1	4.9	1.9
Non-sporulating mycelium	–	–	19.1	6.4	–	3.9	10.8	4.9	–	1.7	19.7	7.1	–	1.9	25.0	9.0	6.8
Total number of isolates	76	48	68	192	84	51	93	228	97	60	66	223	70	52	64	186	829

Table 7

The share of fungi isolated from stem base of spring rye cultivated in pure stand or mixtures at the milk maturity stage (%)

Fungus	Spring rye in pure stand				Spring rye + oats				Spring rye + yellow lupine				Spring rye + blue lupine				Mean
	2000	2001	2002	mean	2000	2001	2002	mean	2000	2001	2002	mean	2000	2001	2002	mean	
Alternaria alternata	1.8	–	–	0.6	–	–	–	–	2.2	–	–	0.7	–	–	–	–	0.3
Aspergillus niger	–	3.4	–	1.1	6.3	–	–	2.1	2.2	2.3	–	1.5	–	–	–	–	1.2
Aureobasidium bolleyi	–	–	–	–	–	3.3	–	1.1	–	–	–	–	–	–	–	–	0.3
Bipolaris sorokiniana	1.8	1.7	–	1.2	–	3.3	–	1.1	–	–	–	–	–	–	–	–	0.6
Fusarium avenaceum	–	12.1	53.3	21.8	–	13.3	58.1	23.8	–	14.0	50.6	21.5	1.0	22.0	65.2	29.4	24.1
Fusarium culmorum	51.8	24.1	17.4	31.1	59.4	43.3	9.3	37.3	68.5	46.5	14.3	43.1	75.3	36.0	10.1	40.5	38.0
Fusarium equiseti	35.5	37.9	21.7	31.7	13.5	26.7	22.1	20.8	16.3	32.6	22.1	23.6	10.3	40.0	21.3	23.9	25.0
Fusarium oxysporum	1.8	–	1.1	1.0	3.1	3.3	–	2.2	–	–	1.3	0.4	3.1	–	1.1	1.4	1.2
Fusarium poae	–	–	–	–	–	–	–	–	3.3	–	–	1.1	–	–	–	–	0.3
Fusarium solani	1.8	1.7	1.1	1.5	–	–	2.3	0.8	–	2.3	–	0.8	–	–	1.1	0.4	0.9
Fusarium sporotrichioides	–	–	3.3	1.1	–	–	4.7	1.6	–	–	6.5	2.2	–	–	–	–	1.2
Fusarium tricinctum	–	3.4	–	1.1	–	6.7	–	2.2	–	2.3	–	0.8	–	2.0	–	0.7	1.2
Fusarium total	90.9	79.3	97.8	89.3	76.0	93.3	96.5	88.6	88.0	97.7	94.8	93.5	89.7	100.0	98.9	96.2	91.9
Mucor spp.	5.5	3.4	–	3.0	15.6	–	–	5.2	2.2	–	–	0.7	8.2	–	1.1	3.1	3.0
Phoma sp.	–	–	–	–	2.1	–	–	0.7	–	–	–	–	–	–	–	–	0.2
Rhizoctonia cerealis	–	1.7	1.1	0.9	–	–	1.2	0.4	–	–	1.3	0.4	–	–	–	–	0.4
Thielavia terricola	–	–	–	–	–	–	–	–	–	–	–	–	2.1	–	–	0.7	0.2
Trichoderma viride	–	5.2	1.1	2.1	–	–	2.3	0.8	5.4	–	3.9	3.1	–	–	–	–	1.5
Non-sporulating mycelium	–	5.2	–	1.1	–	–	–	–	–	–	–	–	–	–	–	–	0.3
Total number of isolates	110	58	92	260	96	30	86	212	92	43	77	212	97	50	89	236	920

in 2001 *F. equiseti* and in 2002 *F. avenaceum* were the common fungi (Table 7). *Rhizoctonia cerealis, B. sorokiniana* and *A. bolleyi* were found less frequently. Cultivation of rye in mixtures did not affect composition of fungal species occurring on the infected spring rye stem bases, either.

Discussion

In this study spring rye root and foot rot diseases occurred with a relatively high intensity. Rye infestation by *Oculimacula* spp. (eyespot) was also high. Fusarium foot rot was mild, while sharp eyespot was sporadic. These rates of spring infection are comparable to those observed in winter form of rye. Similar importance of respective diseases in winter rye was reported by Kurowski (2002). Others, however, pointed out higher infection of winter rye stem base with *Oculimacula* spp. than with *Fusarium* spp. (Głazek et al. 2000, Lemańczyk and Wasilewski 2002). Lemańczyk et al. (2004) found in rye hybrid cultivars the importance of take-all diseases similar to those observed in the present research in the spring form.

What is interesting, the occurrence of eyespot was most intensive. According to Korbas (2008), the cultivation period of spring cereals is too short for them to get high infection with *Oculimacula* spp. Weather conditions favourable for the development of *Oculimacula* spp., recorded in this experiment during the vegetation period, can be the reason for relatively high eyespot symptoms intensity. The highest intensities of eyespot were reported in 2002 when the total rainfall was highest. According to the same author, the occurrence of the disease is mostly affected by rainfall, especially by its frequency.

From the infected rye roots *G. graminis* var. *tritici* was frequently isolated. The fungus is considered one of the main causes of root rot in cereals, including rye (Hollins et al. 1986, Martyniuk 1986, Gutteridge et al. 1993). Cook (2003) claims, however, that rye is less susceptible to infection as compared with wheat and triticale.

The species variation of fungi isolated from stem base of rye was lower than from roots. Among the fungi isolated from stem base *Fusarium* spp. (especially *F. culmorum*, *F. equiseti* and *F. avenaceum*) were dominant species. They were also found dominant on stem base of winter rye form by other authors (Kurowski 2002, Kurowski and Adamiak 2007, Lemańczyk and Wasilewski 2002, Lemańczyk et al. 2004). From the rye stem base *G. graminis* var. *tritici*, *Rhizoctonia* spp., *A. bolleyi* and *Oculimacula* spp. are also isolated (Kurowski 2002, Kurowski and Adamiak 2007, Lemańczyk et al. 2004).

The effect of the companion crop on the health status of spring rye was ambiguous. A much weaker infection with *Fusarium* was reported when rye was grown in mixtures, both with lupines and with oats. A similar relationship in spring barley was earlier reported by Truszkowska et al. (1983) and Vilich-Meller (1992). Others, however, did not find any variation in the occurrence of the disease (Michalski et al. 2000). Healthier roots of rye grown in the mixtures were found

only at an earlier observation stage. The most favourable effect was attributed to lupines. Pięta (1985) and Bais et al. (2006) report on papilionaceous plants exuding different compounds through roots to soil, e.g. free amino acids which affected the pathogens found in the neighbourhood of roots, stimulating or inhibiting germination of their spores and mycelium development. A special importance is attributed to the exuded alkaline amino acids and aromatic amino acids which inhibit the pathogen mycelium development. Slightly less favourable effect was reported for oats. It exudes two groups of secondary metabolites which are considered to play a special role in pathogen inhibition. These are flavonoids and saponins, especially avenacin which inhibits the development of *G. graminis* var. *tritici* (Osbourn 2003, Bahraminejad et al. 2008). However, the effect of those compounds is mainly visible in the successive vegetation period. According to Bahraminejad et al. (2008), however, the extract from oats shoots inhibits the development of neither *R. solani* nor *F. graminearum*.

In the present research no variation was found in the occurrence of eyespot and sharp eyespot. Similar results in barley were also reported by Garrett and Mundt (1999) as well as Michalski et al. (2000).

Streszczenie

CHOROBY POWODOWANE PRZEZ GRZYBY NA KORZENIACH I PODSTAWIE ŹDŹBŁA ŻYTA JAREGO UPRAWIANEGO W SIEWIE CZYSTYM I W MIESZANKACH Z INNYMI ROŚLINAMI

Badania polowe prowadzono w Mochełku (17°51'E, 53°13'N). Oceniano zdrowotność korzeni i podstawy źdźbła żyta jarego uprawianego w czystym siewie i w mieszankach z owsem, łubinem żółtym i łubinem wąskolistnym. Wystąpiło stosunkowo dużo objawów zgnilizny korzeni żyta. Na podstawie źdźbła stwierdzono głównie objawy łamliwości źdźbła, następnie fuzaryjnej zgorzeli podstawy źdźbła, a ostra plamistość oczkowa występowała sporadycznie. Uprawa żyta w mieszankach wpłynęła istotnie tylko na zdrowotność korzeni i porażenie podstawy źdźbła przez *Fusarium* spp. Żyto było najzdrowsze, gdy uprawiano je w mieszankach, zwłaszcza z łubinami. Z porażonych korzeni żyta izolowano głównie *Gaeumannomyces graminis* var. *tritici* i *Fusarium* spp., a z podstawy źdźbła głównie *Fusarium* spp., zwłaszcza *F. culmorum*, *F. equiseti* i *F. avenaceum*. Uprawa żyta w mieszankach nie wpłynęła na skład gatunkowy grzybów izolowanych z jego porażonych korzeni i podstawy źdźbła.

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