THE ROLE OF THE PRECEDING CROP AND WEED CONTROL IN THE TRANSMISSION OF *RHIZOCTONIA CEREALIS* AND *R. SOLANI* TO WINTER CEREALS

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Abstract: Winter cereals (wheat, triticale, rye, barley) grown in experimental fields were assessed for sharp eyespot. Preceding crops (spring cereals and fallow) and weed control (herbicides application, no control) were taken into account. The health status evaluation was carried out at the stem elongation phase and at the milk maturity stage. The macroscopic estimation was accompanied by the analysis of fungal species identified on stem bases and roots, which showed various disease symptoms. The analysis of fungal species from the genus *Rhizoctonia* were especially noted. Mycological analysis of roots was carried out at the seedling growth and stem elongation phase, and stem bases at the seedling growth and milk maturity stage. Infection caused by *Rhizoctonia* spp. was confirmed by polymeraze chain reaction (PCR) assay. The highest infection was noted on wheat followed by triticale, rye and barley. Occurrence of sharp eyespot depended more on weed control than on what the preceding crop had been. At the milk maturity stage, lower severity of sharp eyespot of triticale, rye and barley was noted on plots not treated with herbicides, and on wheat with herbicide application. The research showed a significant effect of the preceding crop only on the health status of wheat. At the milk maturity stage, the highest infection was noted after spring triticale and the lowest after oats. Stems of cereals with sharp eyespot symptoms and healthy stems were settled mainly by *Rhizoctonia cerealis* (wheat – 25.6%, triticale – 12.0%, rye – 22.2%, barley – 11.3%), rarely by *R. solani* (respectively 6.0, 4.0, 2.9 and 1.8%). *Rhizoctonia solani* was isolated more often from roots with true eyespot and Fusarium foot rot symptoms. It may suggest that *R. cerealis* was the main causal agent of sharp eyespot on all tested cereals. The preceding crop did not affect the composition of *Rhizoctonia* species.

Key words: sharp eyespot, *Rhizoctonia cerealis*, *R. solani*, fungi composition, preceding crop, fallow, weed control, herbicide, wheat, triticale, rye, barley

INTRODUCTION

At present, an important problem in the organization of field plant production is a the shortage of preceding crops adequate for cereals, especially winter cereals. As a result, there is a need to grow such crops afterwards. Sometimes there is only a need to do the crop structure of the brownfield land and fallow. Unfortunately, non-compliance with the natural principles of crop rotation leads to a deterioration in the soil properties determining soil fertility. This may result in a greater intensity of the occurrence of agrophages which in turn, leads to decreased yields and deterioration of yield quality. Under such conditions there is a more intensive occurrence of foot and root rot diseases, including take-all (*Gaeumannomyces graminis* (Sacc.) Arx & Olivier), Fusarium foot rot (*Fusarium* spp.), eyespot (*Oculimacula yallundae* (Wallwork & Spooner) Crous & W. Gams, *O. acuformis* (Boerema, R. Pieters & Hamers) Crous & W. Gams and sharp eyespot (*Rhizoctonia cerealis* van der Hoeven).

The results of the research performed so far, in different years and habitat-and-agrotechnical conditions, show that the preceding crop value of respective species and forms of cereals varies. Similarly, reaction to the preceding cereal crop differs. There is, however, little coverage on the phytosanitary value of fallow for cereals. In the soils periodically excluded from agricultural production, there occur changes in the physicochemical and biological properties. These changes can also affect the occurrence of plant pathogens in the soils (Robertson 2002).

Incompliance with the natural principles of crop rotation, also leads to the compensation of some weed species and changes in the structure of weed species. The efficiency and the effectiveness of methods and treatments limiting weed infestation, including the application of herbicides, are also affected. The main sources of weeds are: soils which weeds reach from heavily-weed-infested plantations of crops, or weeds that are present in crop rotation or in the surrounding area of arable fields as well as from the areas partially excluded from agricul-

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tural production. The relationship between reservoir of a pathogen, the weather, and weeds plays a critical role in determining disease incidence and impact. Weeds can interact with pathogen management in several ways, including provision of weed biological control. Weeds can serve as reservoir alternative hosts for pathogens. Weeds may be obligate alternate hosts for some pathogens, and herbicides used for weed control can interact with plant pathogens (Wisler *et al.* 2005). To limit the weed infestation, the application of herbicides which are not neutral to plant pathogens is commonly used. Herbicides have either increased or decreased plant diseases (Altman and Campbell 1977; Sanyal and Shrestha 2008; Velini *et al*. 2010).

Recently in Poland, a clear increase in the occurrence of sharp eyespot has been observed (Kurowski and Adamiak 2007; Lemańczyk 2010a, b). A greater intensity of sharp eyespot was also earlier observed in other countries (Pitt 1966; Clarkson and Cook 1983; Cromey *et al*. 2002; Chen *et al*. 2010). The increased spreading of this disease, despite continuing to grow the cereals (Colbach *et al*. 1997; Żółtańska 2005), can also be a consequence of more favourable weather conditions, earlier sowing and the application of fungicides as plant protection against eyespot (Prew and McIntosh 1975; van der Hoeven and Bollen 1980; Bockus *et al*. 2010). The name "sharp eyespot" comes from the characteristic symptoms. The symptoms most frequently observed in cereals are the dark brown bordered lesions formed on the lower stems of plants. If stems are girdled, the tiller may be stunted and premature, resulting in a white head, and lodging.

Sharp eyespot is caused by the soil-borne fungus *R. cerealis* (teleomorph: *Ceratobasidium cereale* D. Murray & L.L. Burpee). This fungus is prevalent throughout the temperate regions of the world and is capable of infecting many plants of *Poaceae*. Plants may be attacked at any stage of growth. Early infections can result in pre- and post-emergence plant death in seedlings. However, according to Mazzola *et al*. (1996), *R. solani* anastomosis group 4 (AG-4) is also the causal agent of sharp eyespot. In the cereals, a role can also be played by the following AGs: AG-8 (Ogoshi *et al*. 1990; Bockus *et al*. 2010), AG-2 and AG-5 (Mazzola *et al*. 1996; Demerci 1998; Okubara *et al*. 2008) as well as AG-11 and AG-3 (Demerci 1998; Tewoldemedhin *et al*. 2006), AG-9 and AG-10 (Ogoshi *et al*. 1990).

The aim of this research was to compare, under the same habitat and agrotechnical conditions, the effect of weed control and the preceding crop value of spring cereals and fallow, on the occurrence of sharp eyespot in the winter forms of wheat triticale, rye and barley. In addition, the author decided to determine how important *R. cerealis* and *R. solani* are in the occurrence of the symptoms of sharp eyespot and other disease changes.

MATERIALS AND METHODS

The research was performed over the 2002–2005 time period, at the Mochełek Experiment Station (17°51'E, 53°13'N) on the experimental plots of the Department of Plant Production and Experimentation of the University of Technology and Life Sciences in Bydgoszcz, Poland. The carefully carried out experiments were set up on lessive soil, produced from heavy sandy loam, representing very good rye complex. The experiment was carried out in two stages. In the first stage, spring cereals (barley, oats, wheat, triticale) were sown and the object was set aside from the sowing, and grown with self-sown plants and weeds. The cereals constituted the preceding crops for the two-factor field experiment with winter cereals. Then, in all the objects, the weed infestation was differentiated (chemical weed control, weeds not controlled). Weeds which were also in the fallow, were controlled at full tillering the spring cereals with the herbicide Chwastox Trio 540 SL [(300 g/l mecoprop + 200 g/l 2-methyl-4-chlorophenoxyacetic acid (MCPA) + 40 g/l dicamba)] at a dose of 1.5 l/ha. In the fallow, the secondary infestation and the species resistant to the effect of the herbicide, were additionally limited by cutting. Mineral fertilisation that was the same for all the objects, was applied pre-sowing: 50 kg/ha N, 30 kg/ha P_2O_5 and 60 kg/ha K_2O as well as at the stem elongation phase – 30 kg/ha N.

At the second stage, after the harvest of spring cereals, four two-factor experiments were done with winter cereals (Kris wheat, Fidelio triticale, Dańkowskie Złote rye, Gregor barley); the results of which are the core of the study. The experiments were set up in split-plot in four replications. The factor of the first order was the preceding crop: spring barley, oats, spring wheat, spring triticale and fallow. The factor of the second order was a varied weed infestation: chemical weed control, uncontrolled weeds.

The agrotechnical practises of winter cereals on all the objects were the same. Skimming and sow plough were used and soil was additionally treated by pre-sowing with a tillage aggregate. Prior to sowing, fertilisation with phosphorus at a dose of 40 kg/ha P_2O_5 and potassium at 60 kg/ha K_2O was applied. Nitrogen fertilisation was used on two dates: pre-sowing 30 kg/ha N and top fertilisation in spring when vegetation resumed was 60 kg/ha N.

Depending on the research year, wheat, triticale and rye were sown between September 21 and 25 at a sowing rate of 450 grains per m^2. Winter barley was sown between September 13 and 16 at a sowing density of 350 grains per m^2. The sowing material of winter cereals were dressed with the Raxil Gel 206 (200 g/l thiram + 6 g/l tebuconazole) at a dose of 500 ml per 100 kg grain. Diseases and pests were not controlled in the vegetation. The mono- and dicotyledonous weeds were combated in spring, at the cereal stage development BBCH 23–25, with herbicides Patrol 500 SC (500 g/l isoproturon) – 2 l/ha and Mustang 306 SE (6.25 g/l florasulam + 300 g/l 2,4-D) – 0.4 l/ha.

The observations of the occurrence of sharp eyespot on stem bases of winter cereals were made at the seedling growth (GS 13–14 according to Zadoks *et al*. 1974), stem elongation phase (GS 34–36), and milk maturity stage (GS 75–77). Sharp eyespot severity was assessed on each tiller according to the following key, based on that of Clarkson and Cook (1983): 0 – no symptoms of sharp eyespot; 1 – one or more lesions on the leaf sheath, or one

small spot on stem; 2 – more lesions girdling, in total, less than half the stem circumference; 3 – one or more lesions girdling, in total, at least half the stem circumference; 4 – one or more lesions girdling, in total, at least half the stem circumference and stem weakened at lesions. The health status of 25 randomly sampled plants from each plot were analyzed each time. The degrees of infection were converted into the DI (disease index) according to the transformation by Townsend and Heuberger (Wenzel 1948). The analysis of variance was made using AWAR software, developed by The Institute of Soil Science and Plant Cultivation in Puławy. The significance of differences was determined using the Tukey test, at $\alpha = 0.05$. The coefficients of correlations were calculated using Pearson to compare the relationship between the reaction of respective winter cereals species to the preceding crop as well as between the reaction of various cereals to weed control. The statistical calculations were done using statistical package, Statistica v. 9 (StatSoft Poland).

The evaluation of the health status of plants was supplemented by a mycological analysis. At the milk maturity stage, the composition of fungal communities infesting cereals tissues with the symptoms of sharp eyespot was determined, taking the preceding crop into consideration. The share of *R. cerealis* and *R. solani* in a total of all the fungi isolated from healthy and infected stem bases and the roots of cereals was defined. The isolation from the roots was performed at the seedling growth (GS 13–14) and stem elongation phase (GS 34–36), and from the stem base – at the seedling growth (GS 13–14) and milk maturity stage (GS 75–77). From healthy stems and roots, the fungal isolation was made from 30 sections, and from diseased roots 100 fragments were prepared each. The diseased stems were isolated separately according to the symptoms of sharp eyespot, true eyespot and Fusarium foot rot. The separated material was rinsed for 45 minutes under running water and then disinfected in a 1% solution of $AgNO_3$ for 15 seconds. Next, the material was rinsed three times in sterile distilled water for 1 minute each and placed onto the PDAS medium (Potato Dextrose Agar with 50 mg of streptomycin added on 1 l of the medium) on Petri dishes.

The fungal isolates were preliminarily determined according to the genus, applying the mycological keys. To determine the fungi representing genus *Rhizoctonia* down to the species, hyphae staining was applied following the method of Bandoni (1979). To confirm the species representation of the *Rhizoctonia* isolates, an additional the polymeraze chain reaction (PCR) was made using the specific starter type SCAR Rc2 F/R for *R. cerealis* (Nicholson and Parry 1996) as well as ITS1/GMRS-3 for *R. solani* (Johanson *et al*. 1998). The research was performed on selected isolates which, using traditional methods, were determined as *Rhizoctonia*. The isolation of the entire DNA was made according to the modified method by Doyle and Doyle (1990). The PCR reaction was performed using the Core Kit (QIAGEN).

RESULTS

Clear symptoms of sharp eyespot were observed at the stem elongation phase, however the symptoms were much more numerous at the milk maturity stage. In both stages, most of the symptoms were reported in wheat, followed by triticale, rye and barley. In all the winter cereals, most symptoms were reported in 2004. There were fewer symptoms reported in the other two years.

A greater intensity of sharp eyespot in wheat depended significantly on the preceding crop and weed control, which was proved only at the milk maturity stage. Significantly less disease symptoms were noted in the wheat grown after oats. The most disease symptoms were noted in the wheat grown after triticale (Table 1). After the other preceding crops the infection remained average. Interestingly, in 2005 most symptoms were noted after barley. The most symptoms were reported when there was no weed control.

The incidence of sharp eyespot in triticale depended significantly on weed control, which was identified already at the stem elongation phase, but only in 2003 (Table 2). The infection symptoms were only noted when there was no weed control. For mean values there were also fewer symptoms noted when no weed control was applied at the milk maturity stage. Such relationships were recorded in triticale grown after wheat, and triticale as well as fallow. However, in the case of cultivation after barley and oats, much less infection was noted in the plots sprayed with herbicides. No significant effect of the preceding crop on the disease intensity was reported.

A varied intensity of sharp eyespot in rye was noted already at the stem elongation phase (Table 3). In rye grown after triticale and oats, significantly more symptoms were observed when herbicides were used, and when rye was grown after wheat when herbicides were no longer applied. An essential role of weed control was also noted at the milk maturity stage, when more symptoms were visible when herbicides were used. Symptoms were clearly visible when rye was grown after barley and when rye was grown on land that had been previously fallow.

A significant variation in the intensity of sharp eyespot in barley was seen only at the milk maturity stage. For mean-for-years values an essential effect of the preceding crop was reported only in the plots with chemical weed control (Table 4). The use of chemical weed control showed the poorest infection after fallow and the most intensive infection – after triticale. In 2005, most disease symptoms were noted after oats and barley. After the other preceding crops, symptoms were much less numerous. The essential role of weed control was only identified in 2003. In this year, many more disease symptoms were noted when herbicides were applied.

The kind of the preceding crop showed a similar effect on the intensity of sharp eyespot in wheat, triticale and rye. In the case of those cereals, very high values of the coefficient of correlation, ranging from 0.889 to 0.981 were found (Table 5). A slightly different response to the preceding crop was noted for barley since poor relationships between barley and the other cereals were noted. Based on the analysis of regression, one can state that weed control showed a similar effect on the infection of respective cereals by *Rhizoctonia* spp., since the values of the coefficient of correlation ranged from 0.952 to 0.987.

Despite clear symptoms of sharp eyespot, from diseased tissues of cereals many fungi were isolated that

Table 1. The occurrence of sharp eyespot on winter wheat depending on the role played by the preceding crop and weed control – disease index [%]

Years	Weed control [II]	Preceding crop [I]											
		the stem elongation phase						the milk maturity stage					
		B	O	W	T	F	mean	B	O	W	T	F	mean
2003	herbicide	0.20	0.00	0.00	0.00	0.40	0.12	0.20	0.63	0.83	0.60	0.00	0.45
	untreated	0.00	0.20	0.40	0.40	0.40	0.28	0.40	0.40	0.60	1.03	0.40	0.57
	mean	0.10	0.10	0.20	0.20	0.40	0.20	0.30	0.51	0.71	0.81	0.20	0.51
	LSD 0.05	I – ns; II – ns; III (IIxI) – ns; III (IxII) – ns						I – ns; II – ns; III (IIxI) – ns; III (IxII) – ns					
2004	herbicide	0.50	1.00	1.00	1.25	0.75	0.90	1.50	1.25	2.75	6.75	4.75	3.40
	untreated	1.50	0.50	1.50	1.50	0.25	1.05	4.00	3.50	6.50	10.00	4.00	5.60
	mean	1.00	0.75	1.25	1.38	0.50	0.98	2.75	2.38	4.63	8.38	4.38	4.50
	LSD 0.05	I – ns; II – ns; III (IIxI) – ns; III (IxII) – ns						I – 4.748; II – 1.789; III (IIxI) – ns; III (IxII) – ns					
2005	herbicide	0.00	0.50	0.50	0.00	0.00	0.20	2.50	0.25	0.00	0.25	0.50	0.70
	untreated	0.00	0.00	0.00	0.25	0.25	0.10	3.00	1.25	0.00	1.50	1.50	1.45
	mean	0.00	0.25	0.25	0.13	0.13	0.15	2.75	0.75	0.00	0.88	1.00	1.08
	LSD 0.05	I – ns; II – ns; III (IIxI) – ns; III (IxII) – ns						I – 1.601; II – 0.599; III (IIxI) – ns; III (IxII) – 1.945					
Mean	herbicide	0.23	0.50	0.50	0.42	0.38	0.41	1.40	0.71	1.19	2.53	1.75	1.52
	untreated	0.50	0.23	0.63	0.72	0.30	0.48	2.47	1.72	2.37	4.18	1.97	2.54
	mean	0.37	0.37	0.57	0.57	0.34	0.44	1.93	1.21	1.78	3.35	1.86	2.03
	LSD 0.05	I – ns; II – ns; III (IIxI) – ns; III (IxII) – ns						I – 1.595; II – 0.674; III (IIxI) – ns; III (IxII) – ns					

B – spring barley; O – oats; W – spring wheat; T – spring triticale; F – fallow; factor I (preceding crop); factor II (weed control); III – interaction; ns – not significant differences

Table 2. The occurrence of sharp eyespot on winter triticale depending on the role played by preceding crop and weed control – disease index [%]

Years	Weed control [II]	Preceding crop [I]											
		the stem elongation phase						the milk maturity stage					
		B	O	W	T	F	mean	B	O	W	T	F	mean
2003	herbicide	0.00	0.00	0.00	0.00	0.00	0.00	0.43	0.43	0.63	0.43	0.00	0.38
	untreated	0.00	0.00	0.40	0.40	0.00	0.16	0.20	0.20	0.20	0.20	0.00	0.16
	mean	0.00	0.00	0.20	0.20	0.00	0.08	0.31	0.31	0.41	0.31	0.00	0.27
	LSD 0.05	I – ns; II – ns; III (IIxI) – ns; III (IxII) – ns						I – ns; II – ns; III (IIxI) – ns; III (IxII) – ns					
2004	herbicide	0.75	0.75	0.00	1.00	0.25	0.55	0.75	2.50	3.00	2.00	3.00	2.25
	untreated	0.25	0.75	0.25	0.75	0.00	0.40	4.00	3.50	1.75	1.75	1.00	2.40
	mean	0.50	0.75	0.13	0.88	0.13	0.48	2.38	3.00	2.38	1.88	2.00	2.33
	LSD 0.05	I – ns; II – ns; III (IIxI) – ns; III (IxII) – ns						I – ns; II – ns; III (IIxI) – ns; III (IxII) – ns					
2005	herbicide	0.00	0.25	0.00	0.25	0.00	0.10	0.00	0.00	0.00	0.00	0.00	0.00
	untreated	0.00	0.00	0.00	0.00	0.25	0.05	0.00	0.00	0.25	0.00	0.00	0.05
	mean	0.00	0.13	0.00	0.13	0.13	0.08	0.00	0.00	0.13	0.00	0.00	0.03
	LSD 0.05	I – ns; II – ns; III (IIxI) – ns; III (IxII) – ns						I – ns; II – ns; III (IIxI) – ns; III (IxII) – ns					
Mean	herbicide	0.25	0.33	0.00	0.42	0.08	0.22	0.39	0.98	1.38	1.06	1.42	1.04
	untreated	0.08	0.25	0.22	0.38	0.08	0.20	1.40	1.23	0.82	0.65	0.33	0.89
	mean	0.17	0.29	0.11	0.40	0.08	0.21	0.90	1.10	1.10	0.85	0.88	0.97
	LSD 0.05	I – ns; II – ns; III (IIxI) – ns; III (IxII) – ns						I – ns; II – 0.04; III (IIxI) – 0.09; III (IxII) – ns					

B – spring barley; O – oats; W – spring wheat; T – spring triticale; F – fallow; factor I (preceding crop); factor II (weed control); III – interaction; ns – not significant differences

Table 3. The occurrence of sharp eyespot on winter rye depending on the role played by the preceding crop and weed control – disease index [%]

Years	Weed control [II]	Preceding crop [I]											
		the stem elongation phase						the milk maturity stage					
		B	O	W	T	F	mean	B	O	W	T	F	mean
2003	herbicide	1.03	0.83	0.00	1.05	0.00	0.58	1.45	1.48	0.63	0.63	0.63	0.96
	untreated	1.03	0.40	0.60	0.83	0.00	0.57	1.03	1.28	0.63	0.40	0.60	0.79
	mean	1.03	0.61	0.30	0.94	0.00	0.58	1.24	1.38	0.63	0.51	0.61	0.87
	LSD 0.05	I – ns; II – ns; III (IIxI) – ns; III (IxII) – ns						I – ns; II – ns; III (IIxI) – ns; III (IxII) – ns					
2004	herbicide	0.00	0.00	0.00	0.03	0.00	0.01	2.00	1.50	0.50	1.50	2.75	1.65
	untreated	0.00	0.03	0.00	0.00	0.00	0.01	0.00	1.50	0.25	1.25	1.50	0.90
	mean	0.00	0.01	0.00	0.01	0.00	0.01	1.00	1.50	0.38	1.38	2.13	1.28
	LSD 0.05	I – ns; II – ns; III (IIxI) – ns; III (IxII) – ns						I – ns; II – ns; III (IIxI) – ns; III (IxII) – ns					
2005	herbicide	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.75	0.00	0.25	0.20
	untreated	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.75	0.00	0.75	0.25	0.45
	mean	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.38	0.38	0.38	0.25	0.33
	LSD 0.05	I – ns; II – ns; III (IIxI) – ns; III (IxII) – ns						I – ns; II – ns; III (IIxI) – ns; III (IxII) – ns					
Mean	herbicide	0.34	0.28	0.00	0.36	0.00	0.20	1.15	0.99	0.63	0.71	1.21	0.94
	untreated	0.34	0.14	0.20	0.28	0.00	0.19	0.51	1.18	0.29	0.80	0.78	0.71
	mean	0.34	0.21	0.10	0.32	0.00	0.19	0.83	1.08	0.46	0.75	1.00	0.82
	LSD 0.05	I – ns; II – ns; III (IIxI) – ns; III (IxII) – ns						I – ns; II – 0.115; III (IIxI) – 0.347; III (IxII) – ns					

B – spring barley; O – oats; W – spring wheat; T – spring triticale; factor I (preceding crop); factor II (weed control); III – interaction; ns – not significant differences

Table 4. The occurrence of sharp eyespot on winter barley depending on the role played by the preceding crop and weed control – disease index [%]

Years	Weed control [II]	Preceding crop [I]											
		the stem elongation phase						the milk maturity stage					
		B	O	W	T	F	mean	B	O	W	T	F	mean
2003	herbicide	0.43	0.00	0.00	0.20	0.20	0.17	0.83	0.83	0.43	1.48	0.20	0.75
	untreated	0.20	0.00	0.20	0.40	0.00	0.16	0.60	0.60	0.20	0.83	0.20	0.49
	mean	0.31	0.00	0.10	0.30	0.10	0.16	0.71	0.71	0.31	1.15	0.20	0.62
	LSD 0.05	I – ns; II – ns; III (IIxI) – ns; III (IxII) – ns						I – ns; II – 0.19; III (IIxI) – ns; III (IxII) – ns					
2004	herbicide	0.00	0.25	0.25	0.00	0.25	0.15	0.75	1.25	0.75	1.25	0.25	0.85
	untreated	0.00	0.00	0.25	0.00	0.00	0.05	0.75	0.50	2.00	1.00	1.25	1.10
	mean	0.00	0.13	0.25	0.00	0.13	0.10	0.75	0.88	1.38	1.13	0.75	0.98
	LSD 0.05	I – ns; II – ns; III (IIxI) – ns; III (IxII) – ns						I – ns; II – ns; III (IIxI) – ns; III (IxII) – ns					
2005	herbicide	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.75	0.00	0.25	0.00	0.25
	untreated	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.75	0.00	0.25	0.00	0.30
	mean	0.00	0.00	0.00	0.00	0.00	0.00	0.38	0.75	0.00	0.25	0.00	0.28
	LSD 0.05	I – ns; II – ns; III (IIxI) – ns; III (IxII) – ns						I – 0.698; II – ns; III (IIxI) – ns; III (IxII) – ns					
Mean	herbicide	0.14	0.08	0.08	0.07	0.15	0.11	0.61	0.94	0.39	0.99	0.15	0.62
	untreated	0.07	0.00	0.15	0.13	0.00	0.07	0.62	0.62	0.73	0.69	0.48	0.63
	mean	0.10	0.04	0.12	0.10	0.08	0.09	0.61	0.78	0.56	0.84	0.32	0.62
	LSD 0.05	I – ns; II – ns; III (IIxI) – ns; III (IxII) – ns						I – ns; II – ns; III (IIxI) – ns; III (IxII) – 0.811					

B – spring barley; O – oats; W – spring wheat; T – spring triticale; F – fallow; factor I (preceding crop); factor II (weed control); III – interaction; ns – not significant differences

Table 5. The occurrence of sharp eyespot - matrix of correlation coefficients of preceding crop*cereal species and weed control*cereal species

Factor	Preceding crop				Weed control			
	winter wheat	winter triticale	winter rye	winter barley	winter wheat	winter triticale	winter rye	winter barley
Winter wheat	1				1			
Winter triticale	0.943***	1			0.978***	1		
Winter rye	0.889***	0.981***	1		0.987***	0.986***	1	
Winter barley	0.280	0.431*	0.507**	1	0.985***	0.952***	0.987***	1

Significant at: *α = 0.05, **α = 0.01, ***α = 0.001, respectively

Table 6. Fungi occurring on winter wheat stem bases with sharp eyespot symptoms [in %]

Taxon	Preceding crop (2003–2005)					Years			Mean
	B	O	W	T	F	2003	2004	2005	
Rhizoctonia cerealis van der Hoeven	22.2	33.3	11.5	31.6	29.4	7.4	26.2	18.2	17.3
R. solani Kühn	11.1	0.0	1.6	5.3	11.8	0.0	7.1	0.0	2.4
Alternaria alternata (Fr.) Keissl.	0.0	5.6	0.0	5.3	0.0	7.4	0.0	0.0	2.5
Arthrinium phaeospermum (Corda) M.B. Ellis	0.0	0.0	3.3	0.0	0.0	3.7	1.2	0.0	1.6
Aspergillus fumigatus Fresen.	0.0	5.6	0.0	5.3	0.0	0.0	0.0	9.1	3.0
A. niger van Tieghen	0.0	16.7	0.0	0.0	0.0	0.0	0.0	13.6	4.5
Fusarium culmorum (W.G. Sm.) Sacc.	0.0	0.0	14.8	0.0	5.9	14.8	7.1	0.0	7.3
F. poae (Peck.) Wollenw.	0.0	11.1	0.0	5.3	0.0	3.7	2.4	0.0	2.0
Gibberella avenacea R.J. Cook	11.1	0.0	0.0	26.3	0.0	0.0	0.0	31.8	10.6
G. intricans Wollenw.	5.6	0.0	13.1	0.0	0.0	14.8	4.8	4.5	8.0
G. tricincta El-Gholl, McRitchie, Schoult. & Ridings	0.0	0.0	0.0	0.0	5.9	0.0	1.2	0.0	0.4
Haematonectria haematococca (Berk. & Broome) Samuels & Rossman	0.0	0.0	29.5	5.3	5.9	33.3	13.1	0.0	15.5
Microdochium bolleyi (R. Sprague) de Hoog & Herm.-Nijh.	0.0	0.0	6.6	0.0	0.0	7.4	2.4	0.0	3.3
Mucor mucedo Fresen.	0.0	22.2	0.0	0.0	0.0	0.0	4.8	0.0	1.6
Penicillium spp.	33.3	0.0	1.6	5.3	0.0	0.0	3.6	22.7	8.8
Trichoderma koningii Oudem.	0.0	0.0	3.3	0.0	0.0	7.4	0.0	0.0	2.5
Trichoderma spp.	0.0	0.0	4.9	0.0	0.0	0.0	3.6	0.0	1.2
Non-sporulating mycelia	16.7	5.6	9.8	10.5	41.2	0.0	22.6	0.0	7.5
Total number of isolates	18	18	62	19	17	27	84	22	133

B – spring barley; O – oats; W – spring wheat; T – spring triticale; F – fallow

Table 7. Fungi occurring on winter triticale stem bases with sharp eyespot symptoms [in %]

Taxon	Preceding crop (2003–2005)					Years			Mean
	B	O	W	T	F	2003	2004	2005	
Rhizoctonia cerealis van der Hoeven	60.0	0.0	0.0	0.0	0.0	0.0	11.5		5.8
R. solani Kühn	20.0	0.0	0.0	0.0	0.0	0.0	3.8		1.9
Fusarium culmorum (W.G. Sm.) Sacc.	0.0	0.0	0.0	0.0	50.0	0.0	3.8		1.9
Haematonectria haematococca (Berk. & Broome) Samuels & Rossman	0.0	14.3	7.1	50.0	0.0	50.0	3.8		26.9
Mucor mucedo Fresen.	0.0	0.0	7.1	0.0	0.0	25.0	0.0		12.5
Penicillium spp.	0.0	28.6	0.0	0.0	50.0	0.0	11.5		5.8
Trichoderma spp.	0.0	0.0	35.7	0.0	0.0	0.0	19.2		9.6
Non-sporulating mycelia	20.0	57.1	50.0	50.0	0.0	25.0	46.2		35.6
Total number of isolates	5	7	14	2	2	4	26	0	30

B – spring barley; O – oats; W – spring wheat; T – spring triticale; F – fallow

Table 8. Fungi occurring on winter rye stem bases with sharp eyespot symptoms [in %]

Taxon	Preceding crop (2003–2005)					Years			Mean
	B	O	W	T	F	2003	2004	2005	
Rhizoctonia cerealis van der Hoeven	26.7	7.1	20.0	11.1	46.2	16.0	24.0	0.0	13.3
R. solani Kühn	6.7	0.0	0.0	0.0	7.7	0.0	4.0	0.0	1.3
Arthrinium phaeospermum (Corda) M.B. Ellis	0.0	0.0	10.0	0.0	0.0	4.0	0.0	0.0	1.3
Aspergillus niger van Tieghen	6.7	0.0	0.0	0.0	0.0	0.0	0.0	7.1	2.4
Clonostachys rosea (Link) Schroers, Samuels, Seifert & W. Gams	0.0	9.5	0.0	0.0	0.0	0.0	8.0	0.0	2.7
Fusarium culmorum (W.G. Sm.) Sacc.	6.7	16.7	0.0	11.1	7.7	20.0	10.0	0.0	10.0
F. poae (Peck.) Wollenw.	0.0	9.5	0.0	0.0	0.0	0.0	8.0	0.0	2.7
Fusarium sp.	0.0	0.0	10.0	0.0	0.0	0.0	0.0	7.1	2.4
Gibberella avenacea R.J. Cook	6.7	4.8	0.0	0.0	15.4	0.0	6.0	14.3	6.8
G. intricans Wollenw.	6.7	11.9	0.0	0.0	0.0	8.0	8.0	0.0	5.3
G. tricincta El-Gholl, McRitchie, Schoult. & Ridings	0.0	2.4	0.0	0.0	0.0	0.0	2.0	0.0	0.7
G. zeae (Schwein.) Petch	0.0	2.4	0.0	0.0	0.0	0.0	2.0	0.0	0.7
Haematonectria haematococca (Berk. & Broome) Samuels & Rossman	0.0	7.1	0.0	44.4	0.0	20.0	4.0	0.0	8.0
Microdochium bolleyi (R. Sprague) de Hoog & Herm.-Nijh.	0.0	4.8	0.0	11.1	0.0	8.0	2.0	0.0	3.3
Mucor mucedo Fresen.	6.7	2.4	0.0	0.0	0.0	0.0	2.0	7.1	3.0
Oculimacula acuformis (Boerema, R. Pieters & Hamers) Crous & W. Gams	0.0	2.4	0.0	0.0	0.0	4.0	0.0	0.0	1.3
Penicillium spp.	13.3	2.4	30.0	0.0	0.0	4.0	2.0	28.6	11.5
Trichoderma spp.	0.0	14.3	10.0	0.0	0.0	0.0	12.0	7.1	6.4
Non-sporulating mycelia	20.0	2.4	20.0	22.2	23.1	16.0	6.0	28.6	16.9
Total number of isolates	15	42	10	9	13	25	50	14	93

B – spring barley; O – oats; W – spring wheat; T – spring triticale; F – fallow

Table 9. Fungi occurring on winter barley stem bases with sharp eyespot symptoms [in %]

Taxon	Preceding crop (2003–2005)					Years			Mean
	B	O	W	T	F	2003	2004	2005	
Rhizoctonia cerealis van der Hoeven	0.0	0.0	36.4	0.0	20.0	8.7	13.6	0.0	7.4
R. solani Kühn	0.0	0.0	9.1	0.0	0.0	0.0	4.5	0.0	1.5
Arthrinium phaeospermum (Corda) M.B. Ellis	9.1	0.0	0.0	0.0	0.0	4.3	0.0	0.0	1.4
Aspergillus fumigatus Fresen.	0.0	0.0	0.0	6.3	0.0	0.0	0.0	14.3	4.8
A. niger van Tieghen	0.0	11.1	9.1	0.0	0.0	4.3	0.0	14.3	6.2
Microdochium bolleyi (R. Sprague) de Hoog & Herm.-Nijh.	9.1	0.0	9.1	0.0	20.0	0.0	13.6	0.0	4.5
Fusarium culmorum (W.G. Sm.) Sacc.	9.1	11.1	0.0	6.3	20.0	4.3	13.6	0.0	6.0
Gibberella avenacea R.J. Cook	9.1	11.1	0.0	6.3	0.0	0.0	9.1	14.3	7.8
G. intricans Wollenw.	0.0	11.1	0.0	12.5	20.0	8.7	9.1	0.0	5.9
G. zeae (Schwein.) Petch	0.0	0.0	9.1	6.3	0.0	4.3	4.5	0.0	3.0
Haematonectria haematococca (Berk. & Broome) Samuels & Rossman	63.6	22.2	0.0	31.3	0.0	52.2	9.1	0.0	20.4
Mucor mucedo Fresen.	0.0	11.1	0.0	0.0	0.0	4.3	0.0	0.0	1.4
Penicillium spp.	0.0	22.2	27.3	18.8	20.0	4.3	18.2	57.1	26.6
Trichoderma spp.	0.0	0.0	0.0	6.3	0.0	0.0	4.5	0.0	1.5
Non-sporulating mycelia	0.0	0.0	0.0	6.3	0.0	4.3	0.0	0.0	1.4
Total number of isolates	11	9	11	16	5	23	22	7	52

B – spring barley; O – oats; W – spring wheat; T – spring triticale; F – fallow

Table 10. Share [in %] of *R. cerealis* and *R. solani* in total number of fungi isolated from healthy and diseased stem base and roots of winter wheat depending on the role played by the growth stage and preceding crop (2003–2005)

Preceding crop	Fungi	GS 13–14					GS 34–36		GS 75–77			
		DR	HR	O	F	HSB	DR	HR	R	O	F	HSB
Spring barley	Rc	0.0	0.0	0.0	0.0	0.0	1.1	0.0	22.2	2.4	0.0	0.0
	Rs	0.0	0.0	0.0	0.0	0.0	4.3	0.0	11.1	3.5	0.0	0.0
	TNI	15	37	4	13	43	92	37	18	85	42	10
Oats	Rc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33.3	0.0	0.0	0.0
	Rs	0.0	0.0	0.0	0.0	0.0	2.3	0.0	0.0	0.0	0.0	0.0
	TNI	22	14	6	9	44	129	36	18	131	39	13
Spring wheat	Rc	0.0	0.0	0.0	0.0	4.0	0.0	0.0	11.5	0.8	0.0	0.0
	Rs	3.2	0.0	0.0	0.0	0.0	0.9	0.0	1.6	3.3	0.0	0.0
	TNI	31	18	5	3	25	215	62	61	122	27	15
Spring triticale	Rc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.6	0.8	0.0	0.0
	Rs	0.0	0.0	0.0	0.0	0.0	0.8	0.0	5.3	3.3	0.0	0.0
	TNI	41	27	1	17	27	131	38	19	120	37	11
Fallow	Rc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	29.4	2.8	0.0	0.0
	Rs	0.0	0.0	0.0	0.0	0.0	1.6	0.0	11.8	5.5	0.0	0.0
	TNI	17	35	13	10	26	182	25	17	109	77	13
Mean	Rc	0.0	0.0	0.0	0.0	0.8	0.2	0.0	25.6	1.4	0.0	0.0
	Rs	0.6	0.0	0.0	0.0	0.0	2.0	0.0	6.0	3.1	0.0	0.0
	TNI	126	131	29	52	165	749	198	133	567	222	62

DR – diseased roots; HR – healthy roots; O – stems with eyespot symptoms; F – stems with Fusarium foot rot symptoms; HSB – healthy stem base; R – stems with sharp eyespot symptoms; Rc – *R. cerealis*; Rs – *R. solani*; TNI – total number of all isolates

Table 11. Share [in %] of *R. cerealis* and *R. solani* in total number of fungi isolated from healthy and diseased stem base and roots of winter triticale depending on the role played by the growth stage and preceding crop (2003–2005)

Preceding crop	Fungi	GS 13–14					GS 34–36		GS 75–77			
		DR	HR	O	F	HSB	DR	HR	R	O	F	HSB
Spring barley	Rc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	60.0	0.5	0.0	0.0
	Rs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	2.2	0.0	0.0
	TNI	36	36	7	6	30	69	24	5	183	21	30
Oats	Rc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Rs	0.0	0.0	0.0	0.0	0.0	1.8	0.0	0.0	0.0	0.0	0.0
	TNI	15	18	2	21	28	57	32	7	196	56	25
Spring wheat	Rc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0
	Rs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0
	TNI	22	20	6	15	28	154	23	14	136	50	36
Spring triticale	Rc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.2	0.0	0.0
	Rs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.6	0.0	0.0
	TNI	21	33	4	18	27	139	28	2	84	47	29
Fallow	Rc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Rs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	TNI	18	44	5	29	40	59	27	2	138	56	33
Mean	Rc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.0	0.5	0.0	0.0
	Rs	0.0	0.0	0.0	0.0	0.0	0.4	0.0	4.0	1.3	0.0	0.0
	TNI	112	151	24	89	153	478	134	30	737	230	153

DR – diseased roots; HR – healthy roots; O – stems with eyespot symptoms; F – stems with Fusarium foot rot symptoms; HSB – healthy stem base; R – stems with sharp eyespot symptoms; Rc – *R. cerealis*; Rs – *R. solani*; TNI – total number of all isolates

Table 12. Share [in %] of *R. cerealis* and *R. solani* in total number of fungi isolated from healthy and diseased stem base and roots of winter rye depending on the role played by the growth stage and preceding crop (2003–2005)

Preceding crop	Fungi	GS 13–14					GS 34–36		GS 75–77			
		DR	HR	O	F	HSB	DR	HR	R	O	F	HSB
Spring barley	Rc	0.0	0.0	0.0	0.0	5.4	0.0	0.0	7.1	0.0	0.0	9.1
	Rs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	TNI	7	22	0	55	37	94	11	42	66	33	22
Oats	Rc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	11.1	0.0	0.0	0.0
	Rs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	TNI	2	18	5	14	22	75	22	9	98	37	11
Spring wheat	Rc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	26.7	1.0	2.4	0.0
	Rs	0.0	0.0	0.0	0.0	0.0	1.0	0.0	6.7	2.1	0.0	0.0
	TNI	13	34	8	9	28	105	33	15	97	42	23
Spring triticale	Rc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.0	0.0	0.0
	Rs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	TNI	14	15	0	19	22	99	23	10	74	44	16
Fallow	Rc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	46.2	0.0	0.0	0.0
	Rs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.7	0.0	0.0	7.7
	TNI	1	21	1	11	28	82	22	13	127	54	13
Mean	Rc	0.0	0.0	0.0	0.0	1.1	0.0	0.0	22.2	0.2	0.5	1.8
	Rs	0.0	0.0	0.0	0.0	0.0	0.2	0.0	2.9	0.4	0.0	1.5
	TNI	37	110	14	108	137	455	111	89	462	210	85

DR – diseased roots; HR – healthy roots; O – stems with eyespot symptoms; F – stems with Fusarium foot rot symptoms; HSB – healthy stem base; R – stems with sharp eyespot symptoms; Rc – *R. cerealis*; Rs – *R. solani*; TNI – total number of all isolates

Table 13. Share [in %] of *R. cerealis* and *R. solani* in total number of fungi isolated from healthy and diseased stem base and roots of winter barley depending on the role played by the growth stage and preceding crop (2003–2005)

Preceding crop	Fungi	GS 13–14					GS 34–36		GS 75–77			
		DR	HR	O	F	HSB	DR	HR	R	O	F	HSB
Spring barley	Rc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Rs	0.0	5.1	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0
	TNI	64	59	0	3	42	151	31	11	99	23	10
Oats	Rc	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0
	Rs	0.0	0.0	0.0	0.0	0.0	3.8	0.0	0.0	0.0	0.0	0.0
	TNI	14	16	5	16	20	104	25	9	108	33	5
Spring wheat	Rc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	36.4	0.0	0.0	0.0
	Rs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	9.1	1.2	0.0	0.0
	TNI	37	31	6	26	29	215	24	11	85	33	0
Spring triticale	Rc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Rs	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0
	TNI	39	20	4	14	43	172	33	16	138	25	0
Fallow	Rc	0.0	0.0	0.0	0.0	0.0	0.0	0.0	20.0	0.9	0.0	0.0
	Rs	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.9	0.0	0.0
	TNI	6	82	0	13	36	149	29	5	111	24	9
Mean	Rc	0.0	0.0	0.0	0.0	0.0	0.2	0.0	11.3	0.2	0.0	0.0
	Rs	0.0	1.0	0.0	0.0	0.0	1.2	0.0	1.8	0.4	0.0	0.0
	TNI	160	208	15	72	170	791	142	52	541	138	24

DR – diseased roots; HR – healthy roots; O – stems with eyespot symptoms; F – stems with Fusarium foot rot symptoms; HSB – healthy stem base; R – stems with sharp eyespot symptoms; Rc – *R. cerealis*; *R. solani*; TNI – total number of all isolates

were considered sparotrophic for that group of plants as well as the fungi which at the conidial stage represent genus *Fusarium*. On average, the share of *R. cerealis* in wheat was 17.3%, in triticale – 5.8%, in rye – 13.3% and in barley – for 7.8% (Tables 6–9). The share of *R. solani* in respective cereal species accounted for: 2.4, 1.9, 1.3 and 1.5%, respectively. The share of those fungal species differed across the years. For all the cereals investigated, fungal species were the highest in 2004 when there were also the most symptoms of sharp eyespot observed. No clear effect of the preceding crop on the share of *R. cerealis* and *R. solani* of all the fungi isolated from the infected tissues, was reported. Among the other fungal species, *Haematonectria haematococca* (anamorph *Fusarium solani*) was isolated most frequently, especially in 2003, from the cereals tissues showing the symptoms of sharp eyespot. The infected tissues were often infested by *Gibberella avenacea* (anamorph *Fusarium avenaceum*), *G. intricans* (anamorph *F. equiseti*) and *F. culmorum. G. avenacea* was mostly isolated in 2005. *H. haematococca* dominated in the cereals grown after spring forms of the same species. In the case of rye, *H. haematococca* dominated in the cereals that were cultivated after triticale.

Fungi representing the genus *Rhizoctonia,* were also isolated from the stem base showing the disease symptoms typical for infection caused by *Oculimacula* spp. and *Fusarium* spp. (Tables 10–13). Mostly *R. solani* was obtained, and mostly at the end of the vegetation period. *R. solani* was often separated from the tissues, from the symptoms of true eyespot. From healthy stem bases, *R. cerealis* was isolated more often. The fungi were also isolated from both healthy roots and roots demonstrating disease symptoms. *R. cerealis* were much more often obtained when performing the second isolation though *R. solani* remained the dominant species. The amount of those species did not depend on the preceding crop.

The PCR reaction performed using starters Rc2 F/R facilitated the verification of the selected *R. cerealis* isolates, giving an expected product of amplification of the length of 800 pairs of bases (Fig. 1). Besides the PCR reaction, using starters ITS1/GMRS-3 confirmed the occurrence of *R. solani*, giving an expected product of amplification 550 bp (Fig. 2).

DISCUSSION

The applicable literature offers information about the considerable role played by the preceding crop, in the occurrence of sharp eyespot (Colbach *et al*. 1997; Bockus *et al*. 2010). Our own results partially confirm the information found in the literature since most disease symptoms in winter wheat were reported after spring triticale and the least symptoms – after spring triticale or oats. Żółtańska (2005) also found a essentially stronger infection of wheat grown after spring barley, as compared with winter rape. Her results, however, were recorded only in two of the five years of observation. Kurowski and Adamiak (2007) did not confirm that crop rotation in wheat and rye played a considerable role. No significant effect of the preceding crop on the incidence of sharp eyespot was also noted under winter triticale production conditions (Lemańczyk 2010a) and spring cereals (Lemańczyk 2010b). According to Colbach *et al*. (1997), more symptoms of infection with *R. cerealis* are observed when cereals are grown after the plants which are a potential host of that pathogen. They stated that cultivation after plants which are not a host of *R. cerealis,* limited the incidence of sharp eyespot considerably. What is also important, is that the amount of the plant residue from plants on which *R. cerealis* can develop, is in the soil. Growing cereals after a host plant means a greater amount of residue, thus, better conditions for pathogen development (Pitt 1966). In

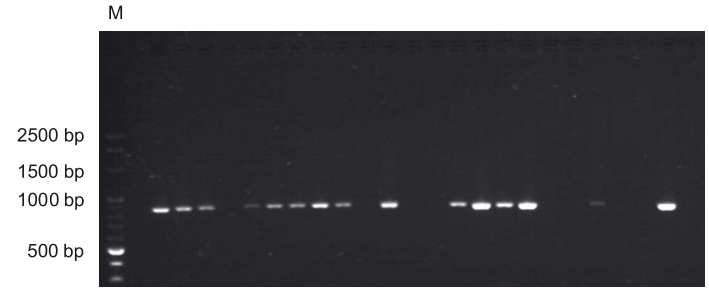

Fig. 1. Confirmation of *R. cerealis* with a PCR assay

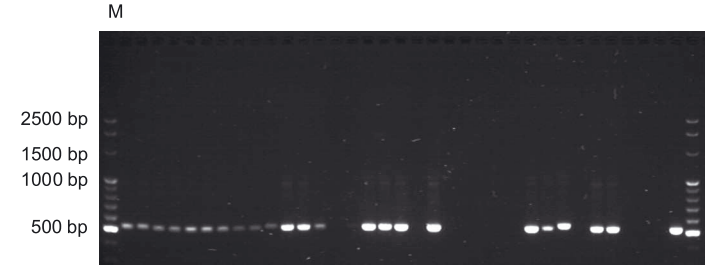

Fig. 2. Confirmation of *R. solani* with a PCR assay

the present research, winter cereals were grown after the various spring cereals which can be attacked by *R. cerealis* as well as by *R. solani*. The research performed on spring cereals commodity plantations, show that most symptoms of sharp eyespot were noted in wheat, followed by triticale, barley and oats (Lemańczyk 2010b), which could have the reason of the infection of wheat grown after oats. However, it is important that residues, on which saprotrophic pathogens in soil develop, are close to the plants. This closeness is especially important for *R. cerealis*, since *R. cerealis* shows a slow linear growth of mycelium. The closer to the inoculum of the host, the higher the probability of infection. The closeness means the mycelium has less distance to cover, to reach the crop and infect it (Colbach *et al*. 1997). A high amount of the preceding crop residue does not automatically mean high disease intensity. The role of the preceding crop can be limited by the fact that fungi representing the genus *Rhizoctonia*, especially *R. solani,* can attack various plant species, not only cereals. Interestingly, however, within that species there occurs a very high variation, and not all the anastomosis groups of that pathogen infect cereals (Sneh *et al*. 1991).

Growing cereals after fallow did not show a considerable effect on the incidence of sharp eyespot. According to Robertson (2002), maintaining fallow enhances the increase in biodiversity and abundance of soil microorganisms. The result is biological suppression of soil. A considerable part of soil microorganisms can also limit the development of *Rhizoctonia* spp. Excluding a field from cultivation for a year, was not sufficient to limit the population of *R. cerealis* and *R. solani*. Those fungi, thanks to the sclerotia they produce, can survive in soil for a few years (Sneh *et al*. 1991).

The hosts of *R. solani* can also be numerous weed species, representing various families (Black *et al*. 1996), whereas for *R. cerealis*, the host is mostly *Poaceae* (Bockus *et al*. 2010). In their earlier publication, Jaskulski and Piasecka (2009) report on the effect of respective spring cereal species as preceding crops, on the weed infestation of winter cereals. Their report was similar, although compared with the other species, oats as a preceding crop considerably limited the weed infestation of winter wheat, spring barley limited weed infestation of winter barley, and spring triticale limited weed infestation of rye. Of all the spring cereals, the lowest weed infestation was in oats. They found that dominant weed species in winter cereals in autumn at all the stands, were as follows: *Viola arvensis*, *Thlaspi arvense*, *Stellaria media*, which can be the hosts of *R. solani* (Peltier 1916), and *Apera spica-venti*, a potential host of *R. cerealis* (Bockus *et al*. 2010). *Elymus repens,* also appeared at the stand after fallow. *Elymus repens,* can be infected by *R. cerealis* (Bockus *et al*. 2010). At that stand, there were also other weeds which were more numerous; and here could be the cause of the limited role played by fallow in the present research. Black *et al*. (1996) found that removing weeds which are the hosts of *R. solani* AG-IA and AG-IB, does not always result in a decrease in plant infection.

The inter cereal most susceptible to weed infestation was wheat, which was earlier presented by Jaskulski and Piasecka (2009). It could be why wheat was the only one in which herbicides had a limited effect on the incidence of sharp eyespot. Fungi representing the genus *Rhizoctonia,* particularly infect weakened plants living under the highest stress. Wheat which was under heavy weed infestation, and which did not have herbicides applied, had to compete with weeds for mineral compounds and water. Thus, wheat was more susceptible to infection. The other cereals investigated show a greater competitiveness for nutrients and at the same time, when exposed to lower weed infestation, they were less susceptible to infection. Colbach *et al*. (1997) report on cereals infected by *R. cerealis.* They stated it is the plant density which is essential. The closer the stems, the greater the probability of infection since the expanding pathogen mycelium has to cover a shorter distance. Once the herbicide application was given up, the plants of rye, triticale and barley were further from one another, which was not favourable to infection.

In the present research, significantly more symptoms of sharp eyespot were found in the plots of triticale, rye and barley treated with herbicides. Other authors reported different results. Kurowski *et al*. (2010), applied herbicides in triticale and observed a limited incidence of sharp eyespot. According to Kurowski and Adamiak (2007), the application of herbicides in rye grown in adequate crop rotation limits the occurrence of sharp eyespot. They found that only in Warko rye grown in monoculture, did herbicide application increased the intensity of the disease. The authors also noted a different reaction across the wheat cultivars to the infection by *R. cerealis* treated with herbicides. In Elena wheat, the use of herbicides helped infection, while in Korweta herbicide application inhibited the disease development. In both cereals the best inhibiting effect was observed when herbicides and fungicides were applied. A different effect of herbicides on the occurrence of sharp eyespot in the present research, could have come from the fact that a varied protection from weeds was already provided in the preceding crops.

The effect of herbicides on plant pathogens is a very complex process. Herbicides can have a direct effect on the pathogen itself as well as an indirect effect by affecting the crop, weeds, mycorrhizae, antagonists, and the effectiveness of fungicides (Lévesque and Rahe 1992; Wisler *et al*. 2005). Herbicides can stimulate the processes of plant resistance to pathogens (Descalzo *et al*. 1990; Lévesque and Rahe 1992). It was also observed, that some herbicides can trigger a considerable increase in fungicide effectiveness. Such a reaction has been confirmed by Kataria and Gisi (1990) who observed that application of the fungicide (cyproconazole) combined with one of the herbicides [dicamba, 4,6-dinitro-o-cresol (DNOC), bromoxynil, ioxynil] inhibited *R. cerealis* infection of wheat seedlings much more effectively than the application of the fungicide alone. Interestingly, dicamba *in vitro*, inhibited the development of *R. cerealis* the least, while under field conditions it was most effective. Much more information on the effect of herbicides on pathogens can be found for *R. solani* than for *R. cerealis* (Altman and Campbell 1977; Lévesque and Rahe 1992).

Many authors report on herbicides enhancing the development of soil microorganisms (Altman and Rovira 1989). There can be a better development of microorganisms in soil after the use of herbicides. This result can be due to a greater secretion by the roots of plants treated with herbicides of various substances stimulating plant development (Lévesque and Rahe 1992).

For example, the foliar application of mecoprop, which was also applied in the present research, contributes to a significant increase in the population of fluorescent *Pseudomonas* spp. in soil. The result is a weaker infection by pathogens (Lévesque and Rahe 1992). According to Rai *et al*. (2000), 2,4-D under laboratory conditions inhibits the development of *R. solani*. According to Busse *et al*. (2004), the application of herbicides in sandy loam soil, found at the Mochełek Experiment Station, can decrease the biomass content of microorganisms. Maybe this is the reason there was no increase in the population of antagonistic organisms in the present research. Neither was there observed an unambiguous effect of those herbicides.

The use of herbicides does not always inhibit the development of pathogens in soil, it can also stimulate pathgenes (Lévesque and Rahe 1992; Smiley and Wilkins 1992; Velini *et al*. 2010). Altman and Rovira (1989) reported 25 herbicides recommended for plant production, which stimulated the growth of *R. solani in vitro*. According to Katan and Eshel (1973), there are four mechanisms which can increase the intensity of diseases, namely by a direct effect of herbicides on pathogen growth, pathogen virulence, susceptibility of the host, and/or changes in the dependences between the pathogen and other soil organisms. Eshel and Katan (1972) concluded that an increase in plant infection by *R. solani* is not a result of a greater susceptibility of the host after the application of herbicides but from the inhibition of the development of antagonistic organisms in soil.

From the stems with the symptoms of sharp eyespot, *R. cerealis* was isolated most often and *R. solani* – much more rarely, which coincides with the reports by Kurowski and Adamiak (2007). Boerema and Verhoeven (1977) consider *R. cerealis* to be the main cause of sharp eyespot, but note that sharp eyespot can also be triggered by *R. solani*. Despite clear symptoms of sharp eyespot, fungi commonly considered saprotrophic for cereals were isolated from tissues. These were fungi representing the genera *Penicillium*, *Trichoderma* and *Aspergillus*, as well as *Fusarium* spp., especially *F. culmorum* and *G. avenacea*. Sometimes, despite clear disease symptoms characteristic for a specific pathogen, other species are isolated which infest the infected tissues secondarily, or take part in mixed infection, including infection by *Fusarium* spp. The pathogen *R. cerealis* is specialized in cereal infection. It grows relatively slowly on artificial media and it is often overgrown with *Fusarium* spp. and saprotrophic fungi (Bateman and Kwaśna 1999). Fungi representing the *Rhizoctonia* genus were rarely isolated from tissues which had symptoms of other diseases. Such tissues were most often infested by *R. solani*, which confirms this pathogenes capacity for saprotrophic development (Sneh *et al*. 1991).

Kurowski and Adamiak (2007) isolated much more *R. cerealis* from the stems of wheat and rye when grown in monoculture as compared with crop rotation, which is not unambiguously confirmed by the present research. Matusinsky *et al*. (2008), applying the PCR technique, did not observe any variation in the intensity of the incidence of *R. cerealis* in wheat grown after various preceding crops. The use of the PCR technique with the application of specific primers type Sequence Characterized Amplified Region (SCAR), made it possible to also confirm the species representation of *R. cerealis* and *R. solani* in the present research. Nicholson *et al*. (2002) and Ray *et al*. (2006) found that the amount of DNA of *R. cerealis,* in relation to total DNA obtained from the plant, was increasing at successive development stages of wheat. Similarly in the present research, many more isolates of *R. cerealis* and *R. solani* were obtained at the end of the plant vegetation period than at the cereals seedling phase, which also coincides with the reports by Bateman (1993).

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