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EFFECT OF CATCH CROP AND CULTIVATION INTENSITY ON THE HEALTH OF SPRING BARLEY

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ABSTRACT

Background. The high share of cereals in the crop structure and the accumulation in the soil of bioactive substances secreted by these plants is worsening soil conditions for cereals grown in subsequent years, as well as leading to an increase in the number of pathogenic microorganisms that infest these plants. The aim of the study was to determine the influence of a stubble catch crop, nitrogen dose and plant protection intensity on the health status of spring barley.

Material and methods. A field study was conducted in the period 2008–2011 in Poland at the Mochełek Experiment Station (17°51' E; 53°13' N) on loamy-sand soil. This study investigated catch crop (field pea, without a catch crop), different levels of intensity of fungicide protection (low, high) and nitrogen fertilizer doses (0, 35, 70, 105 and 140 kg·ha^{-1}) on the health status of root, stem base, leaves and spikes of the spring barley cultivar Tocada.

Results. Cultivation of field pea as a catch crop resulted in an increase in intensity of eyespot, powdery mildew, net blotch as well as of infestation of spring barley spikes by *Fusarium* spp. and *Cochliobolus sativus*. The use of fungicides Capalo 337,5 SE and Falcon 460 EC limited the incidence occurrence of diseases observed on the stem base, leaves and spikes. Fewest eyespot symptoms were observed at 0, 35 and 140 kg·ha^{-1} N, while fewest sharp eyespot symptoms were observed on plots without nitrogen fertilization. The pathogens occurring on diseased spring barley roots were predominantly *Gaeumannomyces graminis*. There were also many *Fusarium* species and *C. sativus* isolates. Infected stems of barley were settled the most often by *Fusarium* spp., *C. sativus* and *Glomerella graminicola*. *Oculimacula yallundae*, *Rhizoctonia cerealis* and *R. solani* were isolated much less frequently.

Conclusion. Increase of nitrogen dose resulted in an increased occurrence of powdery mildew, net blotch, leaf rust, stem base and spike infestation by *Fusarium* spp. and *C. sativus* and a decrease in the severity of root rot.

Key words: catch crop, field pea, fungi, nitrogen rate, spring barley

INTRODUCTION

Barley (*Hordeum vulgare* L.) is the fourth largest major cereal crop grown worldwide, and the third largest major crop grown in Poland (FAO, 2018). The grain is used for feedstock, malting and human consumption. The high potential use of cereal and their relatively cost-effective production has led to poaceous cereal crops, for a dozen or so years, dominating the crop structure in Poland. In 2018 they accounted for 72.1% of the total crop acreage. With such a high share of cereal crops in the crop structure there is an increasing accumulation of bioactive substances secreted by these plants during vegetation

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and released during their residue decomposition (Bais *et al*., 2006; Lemańczyk and Wilczewski, 2006). This process also leads to an increase in the number of pathogenic microorganisms and a decrease in the saprotrophic ones (Kurowski and Adamiak, 2007).

Plants sensitive to inadequate crop sequencing include spring barley, which reacts with a clear decrease in yield resulting from a deterioration of most crop yield structure components following a lack of proper crop rotation (Małecka and Blecharczyk, 2008; Skuodiene and Nekrosiene, 2014). Barley, like wheat, is a cereal crop often attacked by fungal pathogens (Kurowski and Adamiak, 2007; Walters *et al*., 2012). These plants show a high susceptibility to foot and root rot diseases, the intensity of which increases when monoculture and cereal crops rotations are applied (Lemańczyk and Wilczewski, 2014). The effect of these agricultural practices on leaf and spike infection is less considerable (Mathre, 1997; Bingham *et al*., 2008; Walters *et al*., 2012).

One of the methods to alleviate the negative effects of growing cereal crops in rotation is to introduce a catch crop as these plants can perform phytosanitary functions (Małecka and Blecharczyk, 2008). They facilitate an increase in soil bioactivity and the microbiological content of soil biomass (Piotrowska and Wilczewski, 2012). An intensive development of saprotrophic organisms, which follows after introducing organic matter into soil, results in an antagonistic effect towards pathogens and that results in a decrease in the diseases intensity on the crops grown after catch crops (Bailey and Lazarovits, 2003). Growing pea as a catch crop provides yet another advantage, the enrichment of soil with nitrogen. However, intensive, one-sided unbalanced nitrogen fertilization can sometimes lead to an increase in plant susceptibility to infection with pathogens (Mathre, 1997; Newton *et al*., 1998). The aim of the study was to determine the influence of field pea grown as a catch crop, nitrogen dose and plant protection intensity on the health status of spring barley grown in cereal crop rotation, in loamy-sand soil conditions.

MATERIAL AND METHODS

Field experiment

The experimental plots of spring barley cultivar Tocada were established after winter wheat. Each year after the wheat harvest, plowing was done to a depth of about 15 cm. The field pea cultivar Wiato was sown at a rate of 150 kg·ha^{-1} between 5th and 11th of August. The harvested green mass of field pea (25–30 October) was cut and plowed to the depth of the topsoil. Nitrogen fertilization of spring barley was applied according to the scheme of the experiment, while phosphorus (26.2 kg·ha^{-1} P) and potassium (66.4 kg·ha^{-1} K) fertilization was conducted in the spring. Spring barley was sown between 2nd and 4th of April. Weeds were controlled each year with the herbicide Lintur 70 WG (65.9% dicamba + triasulfuron 4.1%) at GS 21–22. Pests, mainly *Lema melanopus* and *Sitobion avenae* were controlled with the insecticide Karate Zeon 050 CS (lambda-cyhalothrin 50 g·dm^{-3}) applied after the crossing of harmfulness thresholds. Fungicides were applied in accordance with the scheme of the experiment. Weather conditions throughout the research period are shown in Table 1.

Samplings and measurements

Barley health evaluation was based on the root, stem base, leaves and spikes infestation rate. In particular the occurrence of foot and root rot diseases and their level of intensity was determined at GS 75–77. An estimation of the health of roots and the stem base infection rate caused by *Oculimacula* spp., *Rhizoctonia* spp., *Fusarium* spp. and *Cochliobolus sativus* (anamorph *Bipolaris sorokiniana*) was conducted using a four degree scale (0–4°), where 0° stands for healthy roots or stems (no symptoms) and 4° for severe infection. The degrees of infection were converted into the disease index (DI) using the formula of Townsend and Heuberger (1943). The incidence and severity of leaf diseases were determined at GS 71–73. The percentage of the two-top-leaves surface with disease symptoms was evaluated. Most attention was paid to the occurrence of net blotch (*Pyrenophora teres*), powdery mildew (*Blumeria graminis*), leaf scald (*Rhynchosporium secalis*) and leaf rust (*Puccinia hordei*). The infection rate on the spike surface caused by *Fusarium* spp. and *C. sativus* was also evaluated. At each measurement the health status of 25 randomly selected plants per plot was analyzed.

Table 1. Weather conditions at the experiment site (Mochełek Experiment Station, Poland)

Month	Precipitation, mm				Temperature, °C		
	2009	2010	2011	1949–2011	2009	2010	2011
March	43.7	28.6	11.7	24.5	2.4	2.4	2.2
April	0.4	33.8	13.5	27.4	9.8	7.8	10.5
May	85.3	92.6	38.4	43.2	12.3	11.5	13.5
June	57.4	18.1	100.8	53.7	14.5	16.7	17.7
July	118.0	107.4	132.5	73.1	18.6	21.6	17.5
Total/Mean	304.8	280.5	296.9	221.9	11.5	12.0	12.3

Isolation and identification of fungi

The evaluation of the health status of roots and stem bases was supplemented by a mycological analysis. At GS 75–77 the composition of fungal communities infesting barley tissues with the symptoms of diseases was determined. The material for analysis was randomly taken from the roots and stem base with disease symptoms, regardless of the experiment combination. A hundred 5 mm sections from diseased roots and a hundred sections from diseased stem bases were prepared. The root and stem pieces were rinsed for 45 minutes in tap water, disinfected for 15 seconds in 1% $AgNO_3$ solution and then rinsed three times in sterile distilled water and placed onto potato dextrose agar (PDA) in Petri dishes with 50 mg of streptomycin per 1 dm^3.

The blotter paper assay method (Limonard, 1968) was used to confirm the species causing disease symptoms on spikes. Each year one hundred barley spikelets with disease symptoms were placed on wet blotting paper in Petri dishes (90 · 16 mm). 10 spikelets per Petri dish were placed equal distances apart. The Petri dishes were incubated at the temperature 22±1ºC under alternate cycles of 12 hours near-ultraviolet light (NUV) and darkness. After 10 days of incubation the spikelets were examined for the associated fungi and the fungi were identified.

Cultures of fungi were identified by their morphology on PDA and synthetic nutrient agar (SNA). To confirm the species classification of the *Oculimacula*, *Rhizoctonia* isolates, *Gaeumannomyces graminis* and some *Fusarium* species, an additional polymerase chain reaction (PCR) was performed. For this purpose we used species-specific primers SCAR (Sequence Characterized Amplified Region), i.e. TyV5F/R for *O. yallundae* and Ta05F/R for *O. acuformis* (Nicholson *et al*., 1997), Rc2F/R for *R. cerealis* (Nicholson and Parry, 1996), ITS1/GMRS-3 for *R. solani* (Johanson *et al*., 1998), JIAF/R for *Gibberella avenacea* (anamorph *F. avenaceum*) (Turner *et al*., 1998), Fc01F/R for *Fusarium culmorum* (Nicholson *et al*., 1998), Fp82F/R for *Fusarium poae* (Parry and Nicholson, 1996) and NS5/GGT-RP for *G. graminis* (Fouly and Wilkinson, 2000). Total DNA was extracted and purified using the modified method described by Doyle and Doyle (1990). The amplification reactions were carried out using a *Taq* PCR Core Kit (QIAGEN Inc., USA). Amplification was carried out in a thermocycler (Eppendorf Mastercycler ep gradient, Germany). The PCR products were separated by electrophoresis in 1.4% agarose gels with 1·TBE buffer and visualized under UV light following ethidium bromide staining.

Statistical analysis

The results were subjected to analysis of variance. The significance of differences between levels of factors and interactions were determined with Tukey´s test, at a significance level of $P<0.05$ for the split-split-plot model.

RESULTS

Of all the foot and root rot diseases of barley, the highest DI value was observed on the roots (Table 2).

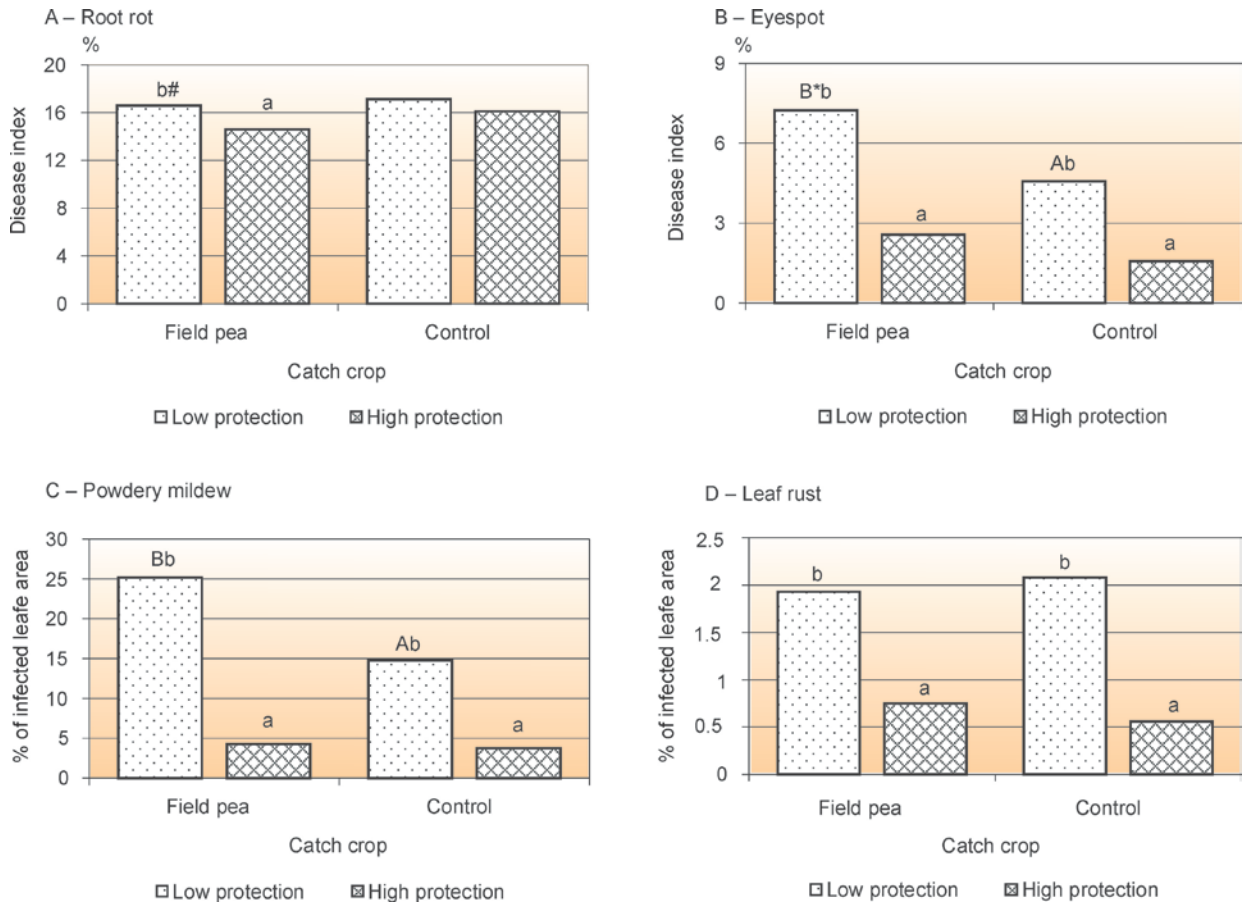
Table 2. Health status of roots, stem base, leaves and spikes of spring barley depending on year, catch crop, intensity of chemical plant protection and rate of nitrogen fertilization

Factor		Root (disease index)		Stem base (disease index)		Leaf (% of leaf surface with disease symptoms)			Spike (% of infected area)
		root rot (complex of fungi)	*Fusarium* spp. + *C. sativus*	eyespot (*O. yallundae*)	sharp eyespot (*Rhizoctonia* spp.)	powdery mildew (*B. graminis*)	net blotch (*P. teres*)	leaf rust (*P. hordei*)	leaf scald (*R. secalis*)
Year	2009	15.0 b	9.9 a	7.46 b	1.86	10.6 a	4.14 a	1.61	0.05
	2010	8.4 a	4.4 a	3.96 ab	0.63	10.9 a	3.97 a	1.83	0.20
	2011	24.9 c	19.4 b	0.54 a	0.52	14.4 b	17.79 b	0.54	0.15
	mean	16.1	11.2	3.99	1.00	12.0	8.63	1.33	0.13
Catch crop	field pea	15.6	11.9	4.90 b	1.11	14.7 b	9.79 b	1.34	0.16
	control	16.6	10.6	1.57 a	0.90	9.2 a	7.47 a	1.32	0.10
The level of fungicide protection	low	16.9	12.8 b	5.91 b	1.23 b	19.9 b	10.68 b	2.00 b	0.21 b
	high	15.4	9.7 a	2.07 a	0.78 a	4.0 a	6.58 a	0.65 a	0.05 a
Rate of nitrogen ($kg \cdot ha^{-1}$)	0	18.6 c	9.1 a	3.27 a	0.65 a	4.6 a	5.35 a	1.11 a	0.06
	35	16.9 b	11.3 b	3.38 a	1.27 c	7.4 b	7.18 b	1.37 bc	0.23
	70	16.3 b	11.8 b	4.58 b	1.17 bc	12.9 c	9.34 c	1.34 b	0.00
	105	14.0 a	11.3 b	5.10 c	1.00 bc	16.6 c	10.49 c	1.33 b	0.11
	140	14.7 a	12.6 b	3.60 a	0.94 ab	18.3 c	10.77 c	1.49 c	0.26

Mean values in the same columns and denoted by different letters vary statistically significantly among themselves ($P < 0.05$)

Weaker fungal infection was recorded on the stem base. The symptoms were mainly caused by *Fusarium* spp. and *C. sativus*. Eyespot and sharp eyespot were noted less frequently. The symptoms which were most frequently observed on barley leaves were powdery mildew and net blotch. Significantly fewer symptoms of leaf rust and leaf scald were observed during the research. On spikes of barley there were observed symptoms of infestation by *Fusarium* spp. and *C. sativus*. The severity of diseases varied over the years. Most symptoms of root rot, powdery mildew, net blotch and infestation of stem base and spikes by *Fusarium* spp. and *C. sativus* were noted in 2011, while the most symptoms of eyespot were in 2009. Experimental factors (catch crop, level of intensity of fungicide protection and rate of nitrogen fertilization) significantly affected the intensity of the observed diseases.

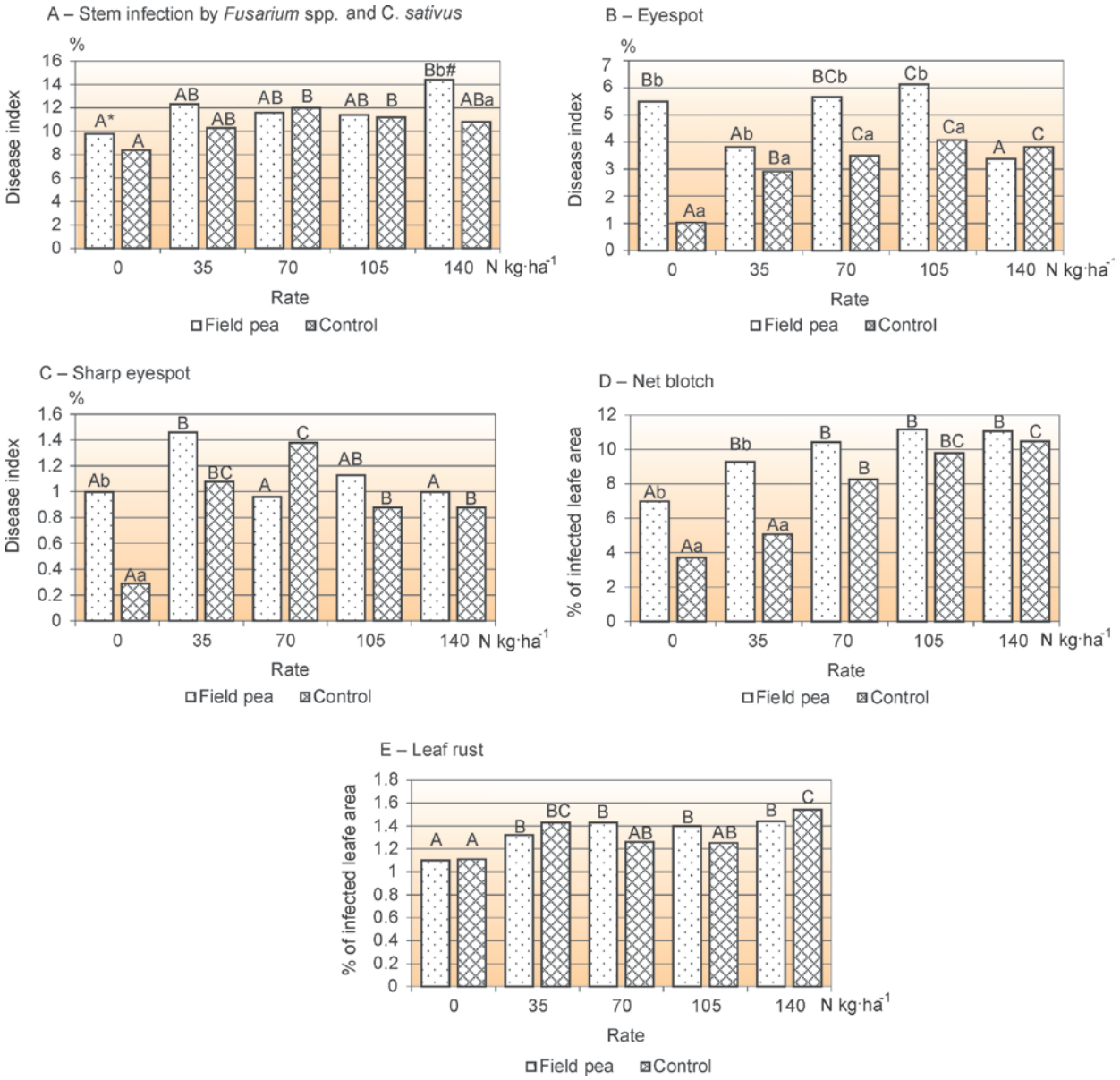
Cultivation of spring barley after field pea grown as a catch crop, as compared with the control, resulted in a statistically significant increase in the intensity of eyespot, powdery mildew, net blotch and spike infestation by *Fusarium* spp. and *C. sativus* (Table 2). The use of field pea did not significantly affect the occurrence of other diseases. The effect of the catch crop depended on fungicide protection level and nitrogen fertilization dose. A higher intensity of eyespot and powdery mildew occurrence was observed mainly at low levels of fungicide protection (Fig. 1B, 1C).



[#] data marked with different small letters differ significantly as a result of plant protection, at $P < 0.05$
* data marked with different capital letters differ significantly as a result of a catch crop, at $P < 0.05$

Fig. 1. Interaction of a catch crop with the intensity of fungicide protection for the health status of spring barley

Additionally, at the highest dose of nitrogen fertilization (140 kg·ha^{-1} N) after the catch crop there was observed a higher infestation of the stem base by *Fusarium* spp. and *C. sativus*, while with zero N fertilization there was an increase in the severity of sharp eyespot symptoms (Fig. 2A, 2C). The effect of the catch crop on the occurrence of net blotch was particularly noticeable at low doses of nitrogen (0 and 35 kg·ha^{-1} N).



data marked with different small letters differ significantly as a result of the catch crop, at $P < 0.05$
* data marked with different capital letters differ significantly as a result of N rate influence, at $P < 0.05$

Fig. 2. Interaction of the catch crop with nitrogen fertilization for the health status of spring barley

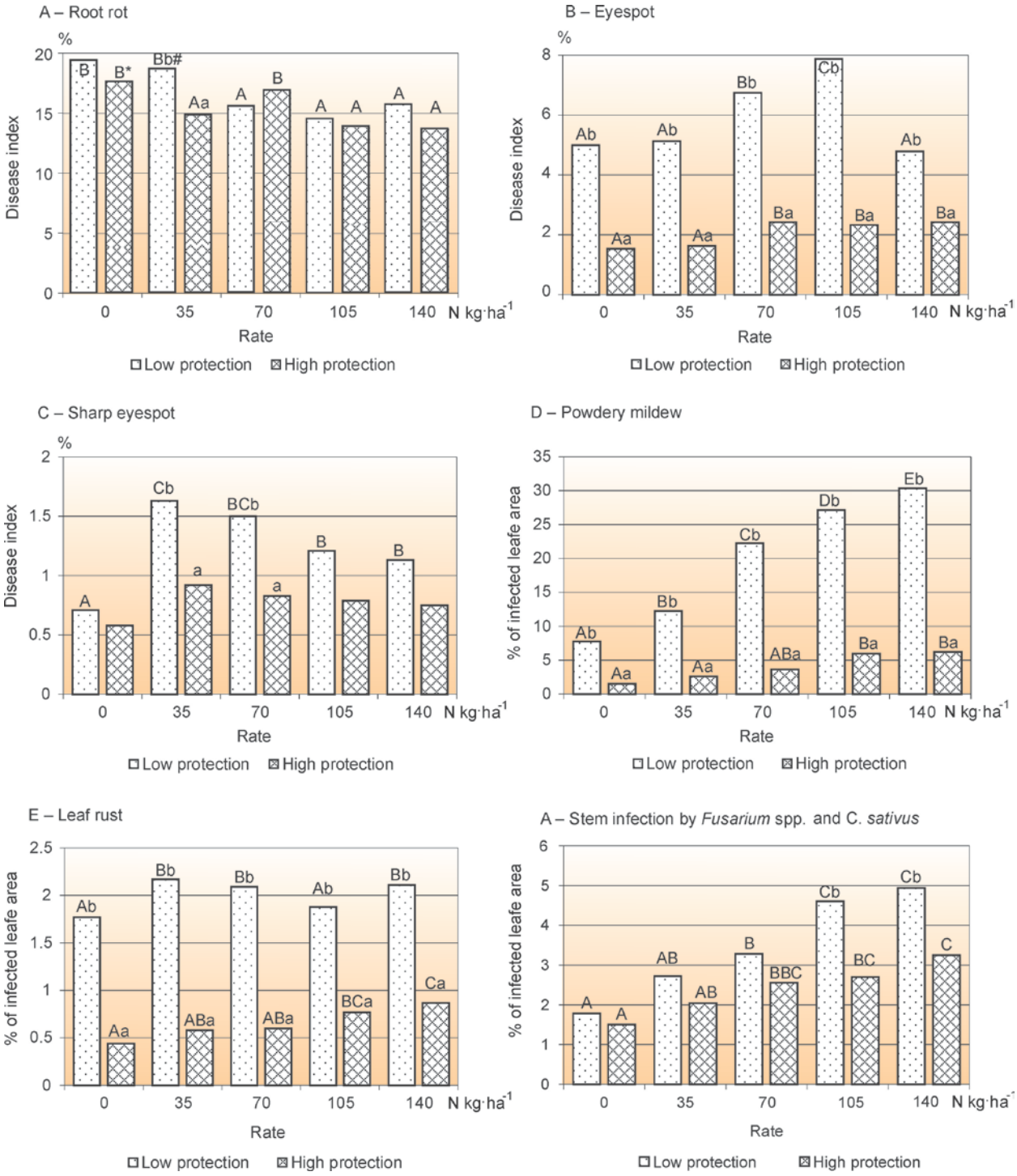
The occurrence of diseases in barley was significantly influenced by the intensity level of chemical protection. The use of fungicides Capalo 337,5 SE and Falcon 460 EC limited the incidence of all diseases observed in the stem base, leaves and spikes (Table 2). The effect of fungicide protection on root infestation was observed only on plots with the catch crop (Fig. 1A) and those fertilized with nitrogen at a dose of 35 kg·ha^{-1} (Fig. 3A). In such conditions fewer symptoms of root rot were observed on barley intensively protected with fungicides.

The dose of nitrogen fertilization significantly differentiated the incidence of all diseases in barley with the exception of leaf scald. Higher nitrogen doses (70, 105 and 140 kg·ha^{-1} N) caused an increased incidence of powdery mildew, net blotch, leaf rust and higher infestation of stem base and spikes by *Fusarium* spp. and *C. sativus*, while the severity of root rot was lower. The highest severity of eyespot and sharp eyespot was observed at an average level of nitrogen fertilization. Fewest eyespot symptoms were observed at 0, 35 and 140 kg·ha^{-1} N, and for sharp eyespot it was on plots without nitrogen fertilization. An interaction between nitrogen dose and the catch crop was found as well as between nitrogen dose and the level of fungicidal protection of barley in relation to disease severity. A pronounced effect of nitrogen fertilization on the occurrence of disease was observed in plots with and without the catch crop (Fig. 2). The severity of disease was observed to be connected to the different levels of nitrogen fertilization and was irrespective of the intensity level of chemical protection (Fig. 3).

Gaeumannomyces graminis was the most common pathogen isolated from infected barley roots and its share in all of the isolates accounted for approximately 40.3% (Table 3). Among the other fungal isolates from roots with disease symptoms there were many the anamorphs of which represented the genus *Fusarium* (28.7%). Those most often isolated were *Fusarium culmorum*, *Haematonectria haematococca* (anamorph *F. solani*), *Gibberella intricans* (anamorph *F. equiseti*) and *F. oxysporum*. There were also many *C. sativus* isolates and to a much lesser extent *Rhizoctonia solani*.

The fungi isolated from stem bases with disease symptoms represented mainly the *Fusarium* genus (45.7%). The isolates obtained included mostly *G. avenacea* followed by *G. intricans*, *F. culmorum* and *H. haematococca*. There were also numerous isolates of *C. sativus* and *Glomerella graminicola*. Less frequently the isolated fungi were represented by *O. yallundae*, *Rhizoctonia cerealis* and *R. solani*. The taxonomy of *O. yallundae*, *R. cerealis*, *R. solani*, *G. avenacea*, *F. culmorum*, *F. poae* and *G. graminis* were additionally confirmed by applying the PCR method using species-specific SCAR primers. The pathogens occurring on necrotic spots on spikelets of barley were mostly represented by *C. sativus* (72.7%) (Fig. 4). Less frequently *Fusarium* spp. were isolated (43.3%).

The catch crop plowed in the autumn as green manure significantly increased the yield of grain of spring barley grown on *Alfisols*. The lower the rate of nitrogen used to grow barley the greater the effect of the catch crop on grain yield was. After the application of 105 or 140 kg·ha^{-1} N, grain yield was not influenced by the catch crop. The increase in grain yield was mainly due to a larger number of ears and grains per spike. The highest grain yield of spring barley was obtained after the application of 70 kg·ha^{-1} N, and significantly lower after the application of 35 kg·ha^{-1} or no nitrogen fertilization. In treatments with a low level of protection, increased fertilization from 70 kg·ha^{-1} to 105 and 140 kg·ha^{-1} resulted in a significant reduction in grain yield.



[#] data marked with different small letters differ significantly as a result of plant protection, at $P < 0.05$
* data marked with different capital letters differ significantly as a result of N rate influence, at $P < 0.05$

Fig. 3. Interaction of the intensity of fungicide protection with nitrogen fertilization for the health status of spring barley

Table 3. Fungi occurring on spring barley roots and stem bases with disease symptoms – total from 2009–2011

Taxon	Root		Stem base
	NI[1]	%[2]	NI
Alternaria alternata (Fries.) Keiss.	6	2.2	4
Aureobasidium pullulans (de Bary) G. Arnaud	–	–	2
Cladosporium herbarum (Pers.) Link. ex Fr.	2	0.7	4
Clonostachys rosea f. *catenulata* (J.C. Gilman & E.V. Abbott) Schroers	3	1.1	2
Cochliobolus sativus (S. Ito & Kurib.) Drechsler ex Dastur	29	10.7	45
Epicoccum nigrum Link	2	0.7	2
Fusarium culmorum (W.G. Smith) Sacc. #	19	7.0	30
Fusarium oxysporum Schlecht.	11	4.1	2
Fusarium poae (Peck.) Wollenw. #	5	1.9	4
Fusarium sporotrichioides Sherb.	2	0.7	–
Gaeumannomyces graminis (Sacc.) Arx et Olivier #	109	40.3	–
Gibberella avenacea R.J. Cook #	12	4.4	49
Gibberella intricans Wollenw.	11	4.1	35
Gibberella tricincta El-Gholl, McRitchie, Schoult. & Ridings	–	–	2
Gibberella zeae (Schwein.) Petch	2	0.7	–
Glomerella graminicola D.J. Politis	–	–	42
Haematonectria haematococca (Berk. & Broome) Samuels & Rossman	16	5.9	21
Microdochium bolleyi (R. Sprague) de Hoog & Herm.-Nijh.	–	–	4
Mucor spp.	1	0.4	5
Oculimacula yallundae (Wallwork & Spooner) Crous & W. Gams #	–	–	10
Penicillium spp.	8	3.0	6
Periconia macrospinosa Lefebvre et JohnsonLefebvre et Johnson	7	2.6	–
Rhizoctonia cerealis van der Hoeven #	–	–	8
Rhizoctonia solani Kühn #	3	1.1	11
Sarocladium strictum (W. Gams) Summerb.	1	0.4	–
Trichoderma harzianum Rifai	2	0.7	–
Trichoderma koningii Oudem.	9	3.3	6
Trichoderma polysporum (Link ex Pers.) Rifai	3	1.1	2
Trichoderma viride Pers. ex Gray	2	0.7	13
Non-sporulating mycelia	6	2.2	4
Total number of isolates	271	100.0	313

the taxonomy of species was confirmed by applying the PCR method using species-specific SCAR primers
[1] NI – number of isolates
[2] % of total number of isolates

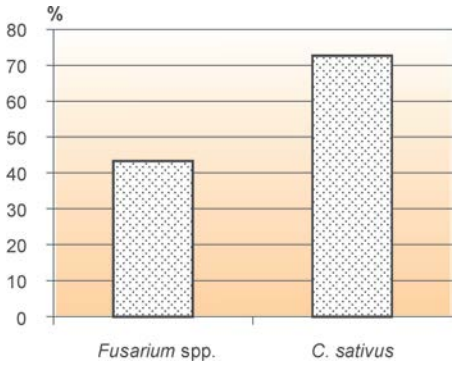


Fig. 4. Per cent of spikelets with disease symptoms colonized by *Fusarium* spp. and *C. sativus* – blotting paper assay

DISCUSSION

The differentiated intensity of disease symptoms found between the years was associated with weather conditions during the barley growing period. Symptoms of leaf spot occur most often in areas where during the cropping season there is high humidity and temperatures between 20 and 30°C (Ghazvini and Tekauz, 2007; Walters *et al*. 2012). High temperatures and rainfall also favor infestation by *G. graminis*. This explains the increased incidence of most diseases in 2011, in which, in June, there was noted the highest amount of rainfall as well as the highest average air temperatures. Such conditions also favored the infestation of spikes, stem bases and roots. *C. sativus* and most *Fusarium* species develop better at higher humidity and air temperature. The development of eyespot is encouraged by rainfall in its early stages of growth and at very high temperatures (Mathre, 1997). Hence, this disease was more common in 2009.

The relatively high root rot severity could be due to the fact that the preceding crop for spring barley was winter wheat. According to earlier reports, cultivation of barley after wheat make favorable conditions for root infestation (Lemańczyk and Wilczewski, 2006). The main causal agent of root rot is *G. graminis* (Mathre, 1997). In our study, it was the most commonly isolated pathogenic species from infected barley roots. Also, other authors have often isolated this fungus from infected barley roots (Kurowski and Adamiak, 2007; Lemańczyk and Wilczewski, 2014). Probably the short time of growing field pea as a catch crop was insufficient for a significant reduction in the population of this pathogen in the soil, leading to a lack of diversity in the severity of root rot. In addition, the roots were often settled by fungi from the genus *Fusarium*, including *F. culmorum*, *H. haematococca*, *G. intricans* and *F. oxysporum*, which are polyphags. These fungi have also been isolated from roots by other authors (Lemańczyk and Wilczewski, 2006; Kurowski and Adamiak, 2007). *Fusaria* are one of the most important pathogens of cereals. They can attack roots and stem base, leaves and spikes. Hence, they were also isolated from leaves and spikes. Stem bases are particularly attacked by *G. avenacea*, *G. intricans*, *F. culmorum* and *H. haematococca* (Lemańczyk and Wilczewski, 2014), which was confirmed in our study as they were the most frequently isolated pathogens from the infected stem bases. *Fusarium* spp. were also found on the spikes of barley.

In our study, *C. sativus* was often isolated from diseased tissues of barley. In Poland, this species is considered to be one of the main causal agent of barley disease symptoms, while in other cereals it is of less importance (Baturo-Ciesniewska, 2011; Lemańczyk and Wilczewski, 2014). It is considered one of the main causal agent of root rot, necrotic lesions on stem base, leaf spot and spike infestation (Mathre, 1997). Also, in our study, it was often isolated not only from roots, but also from stem bases while on spikes it was the dominant species. *G. graminicola* was numerously isolated from stem bases. In Poland, this species is not the most important pathogen of barley, although it can infect roots, stem bases and leaves (Lemańczyk and Wilczewski, 2014).

In our study, *O. yallundae* and *Rhizoctonia* spp. were not the predominant pathogens obtained from infected organs of barley. It has been reported that the DNA content of these pathogens in cereal tissue increases with the growth of plants (Ray *et al*., 2004). Perhaps this is why in the case of spring barley, which is characterized by a short growing season, Lemańczyk and Kwaśna (2013) have reported a low level of severity of eyespot and sharp eyespot. *Oculimacula yallundae* and *R. cerealis* are

characterized by the slow growth of mycelium and probably for this reason they did not manage to infect tissue to a higher degree. Because of the slow growth of mycelium of these species on PDA they are often dominated by saprotrophic fungi. Perhaps it is the reason we found no *O. acuformis*, which according to Ray *et al*. (2004) is characterized by an even slower growth of the mycelium.

The length of the growing season played a lesser role in the infection of cereals by *Fusarium* spp., which are characterized by much faster linear growth of mycelium. Probably for this reason there was observed more symptoms of infection by *Fusarium* spp. and *C. sativus*. In spite of *C. sativus* being characterized by slow growth in Poland it is considered one of the major pathogens of barley (Baturo-Ciesniewska, 2011). Cultivation of field pea as a catch crop did not affect infection by these pathogens. Such a possibility was indicated by earlier studies (Lemańczyk and Wilczewski, 2014). However, it has been suggested that all treatments that enhance the overall amount of microorganisms in the soil, including the cultivation of field pea, reduce infestation by *C. sativus* in cereals due to its low competitiveness against other microorganisms (Bailey and Lazarovits, 2003). In addition, *C. sativus* can survive in the soil in the form of thick-walled spores. From season to season it is also transferred by infested crop residues remaining on the field (Mathre, 1997).

The short time period of field pea cultivation was not sufficient for the development of antagonistic microorganisms in the soil to reduce the growth of soil-borne pathogens that cause not only root rot, but also sharp eyespot and infection of the stem base by *Fusarium* spp. and *C. sativus*. The low severity of sharp eyespot and the fact that *Rhizoctonia* spp. can survive in the soil as saprotroph means that there was no significant effect of the catch crop on their occurrence. Moreover, *Rhizoctonia* spp., as polyphags, are not associated with specific host plants and are also characterized by variable virulence and exhibit high tolerance to environmental factors (Lemańczyk and Kwaśna, 2013). The beneficial effects of catch crop cultivation on spring barley health, especially when the catch crops were non-papilionaceous plants, have been reported in an earlier study (Lemańczyk and Wilczewski, 2006). Other authors also claim that a catch crop is beneficial for the health of cereals grown after it (Małecka and Blecharczyk, 2008). However, in our study, cultivation of field pea as a catch crop contributed to an increase in the severity of eyespot, powdery mildew, and net blotch infestation of spikes by *Fusarium* spp. and *C. sativus* on barley. Wanic *et al*. (2012) also observed an increased development of net blotch on barley after a catch crop grown following spring wheat.

The increase of infection observed on barley grown after a catch crop could be the result of increased plant density. This could affect the severity of disease indirectly by changes in the microclimate within a field. Usually when plants are densely grouped their temperature is more uniform and there is higher humidity, which greatly promotes the infection of plants. Pathogens such as *P. teres*, *B. graminis*, *P. hordei* and *G. graminis* growth best when it is warm with frequent rainfall or high humidity, while development of *R. secalis* is favored by lower temperature and rainfall (Walters *et al*., 2012).

Jensen and Munk (1997) report that use of a catch crop may contribute to an increase in infection due to the accumulation of nitrogen in the soil. The plowed biomass of field pea grown as a catch crop contained a lot of nitrogen, which later could be used by barley (Lemańczyk and Wilczewski, 2006). The significant influence of nitrogen on the occurrence of diseases in barley was also demonstrated in our study. With the increase of nitrogen dose there was observed a higher incidence of powdery mildew, net blotch, leaf rust, infestation of stem base and spikes by *Fusarium* spp. and *C. sativus*, as well as a decrease of root rot severity. Higher infection of leaves, especially by obligatory parasites, at increasing doses of nitrogen are also reported by other authors (Newton *et al*., 1998). At higher nitrogen doses a decrease in the content of phenolic compounds in leaves, which are responsible for the immune processes of plants, has been observed (Lemańczyk and Wilczewski, 2006).

The highest infestation of the stem base by *Rhizoctonia* spp. and *Oculimacula* spp. was observed at an average level of fertilization. However, according to Smiley *et al*., (1996) increasing doses of

nitrogen at a constant level of fertilization with phosphorus and potassium may lead to the stem base of cereals being lignified more slowly, which makes the base more susceptible to infection by *Fusarium* spp., *Oculimacula* spp., *Rhizoctonia* spp. The results obtained by Małecka and Blecharczyk (2008) are in accordance with our results. They found a decrease in infestation of barley roots by *G. graminis* at increasing doses of nitrogen. Balanced and adequate nitrogen fertility for any crop may reduce plant stress, improve physiological resistance, and decrease disease risk. Higher doses of N cause better propagation of plants through having more new roots, moreover, it causes better growth of microorganisms in the soil and that could limit the development of pathogens (Mathre, 1997).

The most important factor limiting the occurrence of diseases in spring barley are fungicides (Walters *et al*. 2012), which was confirmed in our study. The use of fungicides Capalo 337,5 SE (fenpropimorph, epoxiconazole, metrafenone) and Falcon 460 EC (spiroxamine, tebuconazole, triadimenol) in the form of a spray significantly reduced the occurrence of all diseases observed on the stem base, leaves and spikes. According Boys (2012) the active substances in applied fungicides effectively control all diseases of barley leaves. Infestation of the stem base by *Oculimacula* spp. and *Fusarium* spp. was inhibited by fungicide applied at GS 32–33. Infestation of the stem base, leaves and spikes by *C. sativus* was effectively limited by the use of Falcon 460 EC.

CONCLUSIONS

1. Increase of nitrogen dose resulted in an increased occurrence of powdery mildew, net blotch, leaf rust, stem base and spike infestation by *Fusarium* spp. and *Cochliobolus sativus* and a decrease of the severity of root rot.

2. Cultivation of spring barley after field pea grown as a catch crop resulted in a statistically significant increase of eyespot intensity, powdery mildew, net blotch and spike infestation by *Fusarium* spp. and *C. sativus* as compared with the control. The use of field pea did not significantly affect the occurrence of other diseases.

3. A high intensity level of chemical protection, using fungicides Capalo 337,5 SE and Falcon 460 EC, significantly limited the incidence of all diseases observed in the stem base, leaves and spikes of spring barley.

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WPŁYW MIĘDZYPLONU ŚCIERNISKOWEGO I INTENSYWNOŚCI UPRAWY NA ZDROWOTNOŚĆ JĘCZMIENIA JAREGO

Streszczenie

Duży udział zbóż w strukturze zasiewów i kumulowanie w glebie bioaktywnych substancji wydzielanych przez te rośliny, a także nagromadzenie się mikroorganizmów patogenicznych pogarsza warunki glebowe

uprawy zbóż w kolejnych latach. Celem badań było określenie wpływu międzyplonu ścierniskowego, dawki azotu i intensywności ochrony roślin na stan zdrowotny jęczmienia jarego. Badania polowe przeprowadzono w latach 2008–2011 w Stacji Badawczej w Mochełku (17°51' E; 53°13' N), na glebie płowej, należącej do kompleksu żytniego bardzo dobrego. W badaniach sprawdzano wpływ międzyplonu ścierniskowego (grochu), poziomu intensywności ochrony fungicydowej (niski, wysoki) i dawki azotu (0, 35, 70, 105 i 140 kg·ha^{-1}) na stan zdrowotny korzeni, podstawy źdźbła, liści i kłosów jęczmienia jarego odmiany Tocada. Uprawa grochu w międzyplonie ścierniskowym spowodowała nasilenie występowania na jęczmieniu jarym objawów łamliwości źdźbła zbóż i traw, mączniaka prawdziwego zbóż i traw, plamistości siatkowej, a także porażenia kłosów przez *Fusarium* spp. i *Cochliobolus sativus*. Zastosowanie fungicydów Capalo 337,5 SE i Falcon 460 EC ograniczyło występowanie chorób obserwowanych na podstawie źdźbła, liściach i kłosach. Najmniej objawów łamliwości źdźbła zbóż i traw obserwowano po zastosowaniu azotu w dawce 0, 35 i 140 kg·ha^{-1}, a ostrej plamistości oczkowej – na poletkach bez nawożenia azotem. Patogenem najczęściej izolowanym z korzeni jęczmienia jarego z objawami chorobowymi był *Gaeumannomyces graminis*. Stwierdzono na nich również obecność kilku gatunków *Fusarium* i *C. sativus*. Zainfekowane podstawy źdźbła jęczmienia najczęściej były zasiedlane przez *Fusarium* spp., *C. sativus* i *Glomerella graminicola*. Znacznie rzadziej izolowano *Oculimacula yallundae*, *Rhizoctonia cerealis* i *R. solani*.

Słowa kluczowe: dawka azotu, groch, grzyby, jęczmień jary, międzyplon ścierniskowy