

Health Status of Spring Barley Grown on Alfisol as Affected by Catch Crop

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ABSTRACT

Aims: The aim of this study was to evaluate the effect of field pea grown as a catch crop and used for green manure on the health of spring barley grown in cereal crop rotation.

Study design: The experiment was carried out in the randomized block design with four replications.

Place and Duration of Study:

A field experiment was carried out in the years 2008–2011 at Mochelek (17°51'E; 53°13'N), the Experiment Station of the University of Technology and Life Sciences in Bydgoszcz, Poland.

Methodology: The experimental factor was made up by the manner and the time of the catch crop biomass incorporation into the soil: the catch crop plowed-in in autumn; catch crop left as mulch for winter and incorporated in spring; control. The evaluation of the health of roots, stem base and spikes was complemented by mycological analysis.

Results: Catch crop has an ambiguous effect on the health of barley. Although for the Aaveraged over of the three years it significantly decreased the stem infection caused with *Fusarium* spp. and *Cochliobolus sativus* and leaf infection with *Puccinia hordei*. On the other hand, the use of cover crop it also increased leaf infection with *Blumeria graminis* and *Rhynchosporium secalis* as well as spike infestation with *Fusarium* spp. and *C. sativus*. There was no significant effect of catch crop on the occurrence of eyespot, sharp eyespot, root rot and net blotch. The pathogens which occurred on diseased roots were predominantly *Gaeumannomyces graminis*. There were also many *Fusarium* and *C. sativus* isolates. The infected stems were most often infested by *Fusarium* spp., *C. sativus* and *Glomerella graminicola*. The pathogens on necrotic spots on barley spikelets were mostly represented by *C. sativus* and less frequently – by *Fusarium* spp.

Conclusion: Catch crop decreased the stem infection with *Fusarium* spp. and *C. sativus* and leaf infection with *P. hordei*. It also contributed to the increase in leaf infection with *B. graminis* and *R. secalis* and spike infestation with *Fusarium* spp. and *C. sativus*.

Keywords: catch crop, diseases, field pea, fungi, green manure, health, mulch, spring barley.

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1. INTRODUCTION

28 Barley (*Hordeum vulgare* L.) is the fourth major crop grown in Poland [1]. The relatively cost-
29 effective cereals production and a large potential of their use has made cereal crops
30 dominate the crop structure in Poland, in 2013 accounting for 72.6% of the total crop
31 acreage in 2013. Often such situation forces the cultivation of a cereal crop after itself, which
32 leads to a decrease in the grain yield. Growing cereals after cereal crops, including barley,
33 can intensify the disease infection of the roots and stem base [2,3,4]. Its effect on leaf and
34 spike infection is less considerable [5,6,7]. With a large share of cereals in the crop
35 structure, there is an accumulation of pathogens and a decrease in the saprotrophic
36 microorganisms in soil [3], which has an unfavourable effect on an increase and competition
37 of crops towards agrophages [4]. It also leads to an accumulation of unfavourable
38 substances secreted by plants during the growing season and released during the
39 decomposition of their residue [3,8,9].

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41 To limit the grain yield losses, due to an inadequate crop rotation, in practise, one often
42 intensifies the chemical plant control and mineral fertilisation. Such measures do not always
43 bring expected effects—results and, additionally, excessive amounts of chemicals in
44 production, accompanied by a failure to comply with the principles of good agricultural
45 practise, can pollute soil and ground waters [5,10]. With that in mind, one searches for such
46 agricultural production intensification methods which would be safe for the environment and
47 facilitate while maintaining sustainable agricultural development [11]. Besides compliant with
48 the European Union regulations (Directive 2009/128/EC) which provide that the EU member
49 states are obliged to implement the principles of integrated plant protection, it cannot be only
50 limited to the use of chemical plant protection agents. One must use such solutions which
51 will lead to maintaining agrophages at the level which would not be harmful for the crop and
52 will facilitate producing a healthy yield with minimum disturbances of the agricultural
53 ecosystem operation.

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55 The negative effects of growing cereal crops after themselves can be ameliorated through
56 the introduction of catch crop as plants performing phytosanitary functions [2,3,12]. Their
57 special role involves a comprehensive effect on biological, physical and chemical soil
58 properties and limiting nutrients leaching from it. An intensive activity of saprotrophic
59 microorganisms which follows after introducing organic matter to the soil [13,14] results in an
60 antagonistic effect towards to the pathogens, leading to a decrease in the diseases severity
61 on the plants grown thereafter [15]. Those features have made the catch crops become an
62 indispensable component of crop rotations in integrated plant protection.

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64 The aim of this study was to evaluate the effect of field pea grown as a catch crop and used
65 for green manure on the health status of spring barley cultivar, 'Tocada', grown in cereal
66 crop rotation.

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2. MATERIAL AND METHODS

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2.1 Field Experiment

The field experiment was carried out over 2008–2011, at Mochelek Experiment Station, in
the vicinity of Bydgoszcz, mid-west Poland (17°51' E, 53°13' N). The research was
performed in the a randomized block design with four replications on light loamy-sand soil
(on Alfisol). The plot was 250 m² in size. Field pea (*Pisum sativum* L.), cultivar 'Wiato', grown

as a catch crop, was sown 7–13 August in 2008, 2009 and 2010 after the harvest of winter wheat and used as green manure for the following spring barley. The experiment factor was made up by the manner and time of the catch crop biomass incorporation into soil: A – catch crop plowed-in in autumn – using autumn plowing; B – catch crop left as mulch for winter and incorporated in spring – using disking; C – control – without catch crop. The plants in treatment A were harvested using a sickle bar mower from October 15 to November 3. Later soil in treatments A and C was plowed to the depth of 27 cm. In treatment B field pea was left uncut over winter. In spring the pea biomass was cut and mixed with soil using disk cultivator.

Spring barley, cultivar 'Tocada', was sown from March 31 to April 3 over 2009–2011, using a row drill in treatments A and C and a drill equipped with coulters in treatment B. Before sowing, the barley grains were treated with Kinto Duo 080 FS (triticonazole 20 g·dm⁻³ + prochloraz 60 g·dm⁻³). At the stem elongation phase (growth stage (GS) 32–33 according to Zadoks et al. [16] scale) the plants were sprayed with Capalo 337.5 SE (fenpropimorph 200 g·dm⁻³ + epoxiconazole 62.5 g·dm⁻³ + metrafenone 75 g·dm⁻³) at 1.5 dm³·ha⁻¹. The weather conditions throughout the research period are shown in Table 1. The highest amount of precipitation from March to July was in 2009 (304.8 mm) and the lowest in 2010 (280.5 mm). Mean daily air temperature was highest in the growing season of 2011 (12.3°C), while the lowest – the growing season of 2009 (11.5°C).

Table 1. Weather conditions in the growing season of spring barley at the experiment site

Months	Temperature (°C)				Precipitation (mm)			
	2009	2010	2011	1949–2011	2009	2010	2011	1949–2011
March	2.4	2.4	2.2	1.9	43.7	28.6	11.7	24.5
April	9.8	7.8	10.5	7.4	0.4	33.8	13.5	27.4
May	12.3	11.5	13.5	12.7	85.3	92.6	38.4	43.2
June	14.5	16.7	17.7	16.3	57.4	18.1	100.8	53.7
July	18.6	21.6	17.5	18.0	118.0	107.4	132.5	73.1
Mean/Total	11.5	12.0	12.3	11.3	304.8	280.5	296.9	221.9

2.2 Samplings and Measurements

The barley health status was estimated based on the root, stem base, leaves and the spike infestation rate. The occurrence of foot and root rot diseases and their intensity were determined at the milk stage (GS 75–77). The evaluation of health status of roots and stem base infection rate caused by *Rhizoctonia* spp., *Oculimacula* spp., *Fusarium* spp. and *Cochliobolus sativus* (anamorph *Bipolaris sorokiniana*) was carried out using the 0–4 degree scale (0° - healthy, no symptoms, 4° - severe infection). The degrees of infection were converted into the DI (disease index) according to the transformation of Townsend and Heuberger [17]. The severity of leaf diseases was assessed at growth stages (GS 71–73). Thisere was evaluated – assessed as the percentage of the two-top-leaves surface with disease symptoms. The occurrence of net blotch (*Pyrenophora teres*), powdery mildew (*Blumeria graminis*), leaf scald (*Rhynchosporium secalis*) and leaf rust (*Puccinia hordei*) was assessed. The infection rate on the spike surface caused by *Fusarium* spp. and *C. sativus* was also evaluated. Each time the health status of 25 randomly chosen plants per plot were assessed.

2.3 Statistical Analysis

The results were subjected to the one-two-way analysis of variance, and then combined

analysis over the years synthesis for many-year experiments. The significance of differences between the factor levels were determined with the Tukey test, at the significance level of $P=0.05$.

2.4 Isolation and Identification of Fungi

The health of stem bases and roots was evaluated applying the mycological analysis. The material for the analysis was taken from the stem base and roots with disease symptoms, regardless of the experiment factor. A hundred of 5 mm scraps from diseased stem bases and roots and a hundred scraps from diseased roots were sampled. The material was rinsed for 45 minutes in tap water, disinfected for 15 seconds in 1% AgNO_3 and then rinsed in sterile distilled water and placed onto acidified PDA (Potato Dextrose Agar) with 50 mg of streptomycin per 1 dm^3 , in Petri dishes.

To confirm the fungi causing disease symptoms on spikes, the blotting paper assay method [18] has been used. Each time a hundred of barley spikelets with disease lesions were placed on wet blotting paper in Petri dishes. Three sheets of sterilized paper were moistened with sterile distilled water and placed in sterilized plastic Petri dishes. The Petri dishes were incubated at the temperature of $22\pm1^\circ\text{C}$ under alternate cycles of 12 hours near-ultraviolet light (NUV) and darkness. After ten days of incubation the spikelets were checked for the associated fungi.

The isolates of fungi were determined according to the species, applying the mycological keys. To confirm the species representation of the *Gaeumannomyces graminis*, *Rhizoctonia*, *Oculimacula* isolates and some *Fusarium* species, an additional polymerase chain reaction (PCR) was performed. For this purpose, we use a species-specific SCAR primers (Sequence Characterized Amplified Region), i.e. NS5/GGT-RP for *G. graminis* [19], Rc2F/R for *R. cerealis* [20], ITS1/GMRS-3 for *R. solani* [21], Ta05F/R for *O. acuformis* and TyV5F/R for *O. yallundae* [22], JIAF/R for *Gibberella avenacea* (anamorph *F. avenaceum*) [23], Fp82F/R for *Fusarium poae* [24], and Fc01F/R for *Fusarium culmorum* [25]. Total DNA was isolated using the adapted method described by Doyle and Doyle [26]. The amplification reaction was performed with the Taq PCR Core Kit (QIAGEN Inc., USA) in a final volume of $12.5 \mu\text{L}$, consisting of $2.5 \mu\text{L}$ of the solution containing the fungal DNA, $0.25 \mu\text{L}$ dNTP mix, $2.5 \mu\text{L}$ $5\times$ buffer Q, $1.25 \mu\text{L}$ $10\times$ PCR buffer, $0.5 \mu\text{L}$ magnesium chloride, $0.1 \mu\text{L}$ of Taq DNA polymerase and 0.75 each of the primers. Amplification was carried out in Mastercycler ep gradient thermocycler (Eppendorf, Germany). The PCR products were separated by electrophoresis (4 V/cm) in 1.4% agarose gels with $1\times$ TBE buffer (89 mM Tris-borate and 2 mM EDTA) and visualised visualized under ultraviolet light following ethidium bromide staining.

3. RESULTS

In years 2009–2011 the severity of diseases in spring barley was relatively low. The highest disease index value for all the foot and root rot diseases was observed on the roots of all the foot and root rot diseases in spring barley (Table 2). Less intense fungal infection was noted on stem base. The symptoms were mainly caused by *Fusarium* spp. and *C. sativus*. The eyespot and sharp eyespot symptoms were substantially less frequent.

Catch crop plowing in autumn significantly decreased the stem base infection with *Fusarium* spp. and *C. sativus*. A significant differentiation in the root rot occurrence was observed only in 2011. The lowest disease symptoms were recorded on the mulched plots and the highest

177 | – for the control. There was no significant effect of the test agent on the occurrence of
 178 eyespot and sharp eyespot.
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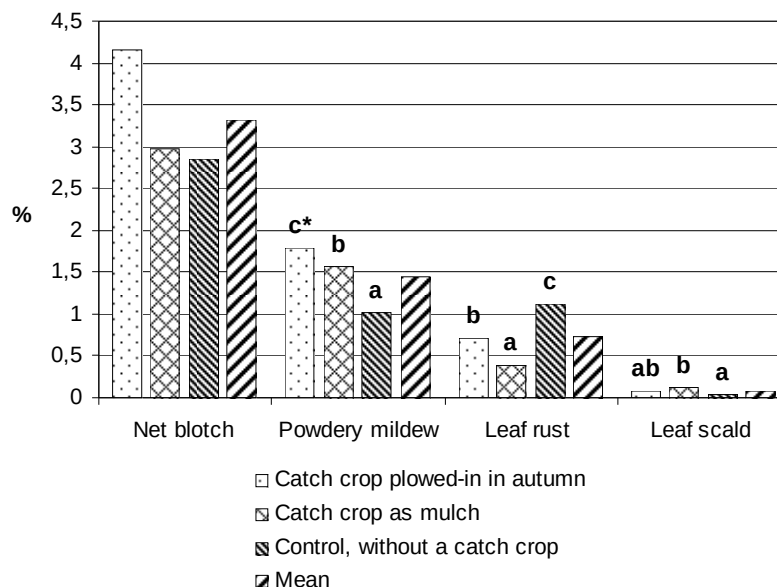
Table 2. Health status of roots and stem base of spring barley

Disease	Catch crop	2009		2010		2011		Mean	
		DI	%	DI	%	DI	%	DI	%
Root rot (complex of fungi)	A	21.0	40	32.5	88	25.5 ab	58 ab	26.3	62.0
	B	30.5	54	25.3	73	19.3 a	54 a	25.0	60.3
	C	33.3	50	24.5	77	33.3 b	64 b	30.4	63.7
	Mean	28.3	48.0	27.4	79.3	26.0	58.7	27.2	62.0
Stem base infected with <i>Fusarium</i> spp. and <i>Cochliobolus</i> <i>sativus</i>	A	6.25 a	24 a	2.25	9	18.75	53	9.08 a	28.7 a
	B	6.00 a	20 a	3.50	14	19.75	61	9.75 ab	31.7 ab
	C	9.50 b	32 b	3.00	12	22.00	66	11.50 b	36.7 b
	Mean	7.25	25.3	2.92	11.7	20.17	60.0	10.11	32.4
Eyespot (<i>Oculimacula</i> <i>yallundae</i>)	A	3.00	8	5.50	18	0.25	1	2.92	9.0
	B	3.50	11	1.75	6	0.00	0	1.75	5.7
	C	4.25	11	2.00	7	0.50	2	2.25	6.7
	Mean	3.58	10.0	3.08	10.3	0.25	1.0	2.31	7.1
Sharp eyespot (<i>Rhizoctonia</i> <i>cerealis</i>)	A	3.00	11	0.75	3	0.25	1	1.33	5.0
	B	1.75	5	0.25	1	1.50	3	1.17	3.0
	C	2.25	8	0.25	1	0.00	0	0.83	3.0
	Mean	2.33	8.0	0.42	1.7	0.58	1.3	1.11	3.7

A – catch crop plowed-in in autumn; B – catch crop as mulch; C – control, without a catch crop;

DI – disease index in %; % – per cent of plants/stems with disease symptoms;

Means marked with different letters within particular columns are significantly different at $P=0.05$



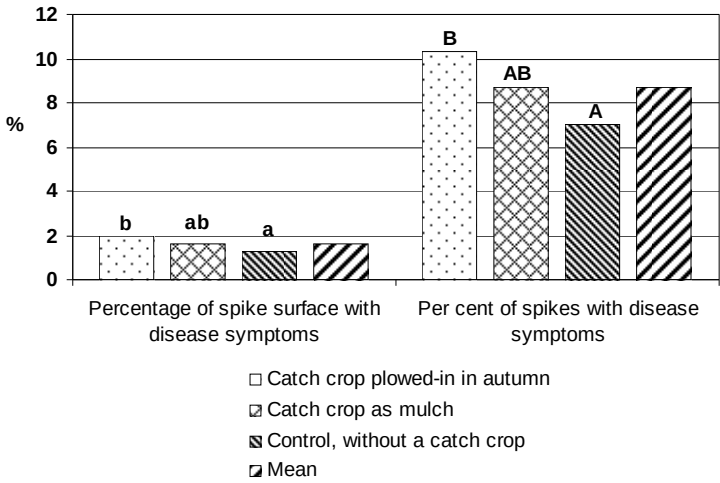
* Means marked with different letters within particular columns (for particular diseases) are significantly different at $P=0.05$

Fig. 1. Percentage of leaf surface with disease symptoms (2008–2011)

198 The symptoms which were most frequently observed on barley leaves were net blotch
 199 (Fig. 1). The disease severity depended on the catch crop applied only in 2010. The highest
 200 net blotch symptoms were noted on the mulched plots and the lowest— on the control.
 201 Significantly fewer symptoms of powdery mildew, leaf rust and then leaf scald were
 202 observed during this research. For the average of the three years, powdery mildew and leaf
 203 scald were least intensive in the control, and the catch crop increased the infection rate. The
 204 fewest symptoms of leaf rust were recorded on the barley grown on the mulched plots and
 205 most—in the control, without a catch crop. A significant effect of the catch crop on the
 206 occurrence of powdery mildew, leaf scald and leaf rust was observed only for the years
 207 average. In respective research years the variation was not significant, however, in each
 208 research year, although the trend was the same as for the years average. the tendencies
 209 were the same as for the years average. With that in mind, despite a considerable variation
 210 in respective years, drawing on the statistical analysis, a considerable variation for the years
 211 average was proven.

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 213 On the spring barley spikes, there were observed the symptoms of infestation with genus
 214 *Fusarium* and *C. sativus* fungi. For the average of three years the least severe disease
 215 symptoms were reported for the control, and the plowing catch crop in autumn increased the
 216 severity of symptoms (Fig. 2). In respective individual research years the variation was not,
 217 however, significant, however, there were noted tendencies similar trends to those for the
 218 years average.

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Fig. 2. Spike infection with *Fusarium* spp. and *Cochliobolus sativus* (2008–2011)

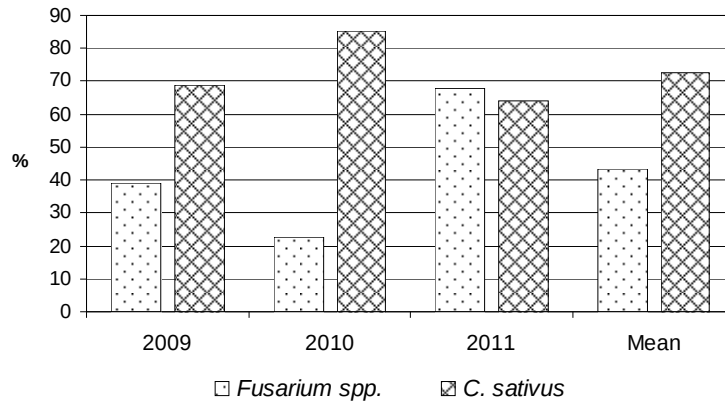


Fig. 3. Per cent of spikelets with disease symptoms colonized by *Fusarium* spp. and *Cochliobolus sativus* – blotting paper assay

The pathogens occurring on necrotic spots on spring barley spikelets were mostly represented by *C. sativus* (72.7%) (Fig. 3). *Fusarium* genus fungi were less frequently isolated (43.3%).

Gaeumannomyces graminis was the most common pathogen isolated from infected barley roots, whose share in all the isolates accounted for approximately 39.1% (Table 3). Also a significant number of fungi at the anamorph stage were identified to represent *Fusarium* genus, where *Fusarium culmorum*, *Haematonectria haematococca* (anamorph *F. solani*) and *Gibberella intricans* (anamorph *F. equiseti*) dominated. There were also many *C. sativus* isolates, and much fewer *Rhizoctonia solani*. The fungi isolated from the stem base represented mainly the *Fusarium* genus (56.4%). The isolates included mostly *F. culmorum*, followed by *G. intricans*, *G. avenacea* and *H. haematococca*. Many of the isolates of *C. sativus* and *Glomerella graminicola* were also reported. Clearly less frequently isolated fungi included: *O. yallundae*, *R. cerealis* and *R. solani*. The taxonomy of *O. yallundae*, *R. cerealis*, *R. solani*, *G. avenacea*, *F. culmorum* and *F. poae* was confirmed additionally by applying the PCR method using species-specific SCAR primers.

Table 3. Fungi occurring on spring barley roots and stem bases with disease symptoms

Taxon	Roots				Stem base			
	2009	2010	2011	Mean (Total)	2009	2010	2011	Mean (Total)
<i>Alternaria alternata</i> (Fries.) Keiss.	6.2 (5)	4.5 (3)	5.3 (4)	5.3 (12)	–	–	–	–
<i>Cochliobolus sativus</i> (S. Ito & Kurib.) Drechsler ex Dastur	2.5 (2)	10.3 (7)	10.6 (8)	7.8 (17)	9.7 (9)	11.2 (11)	22.2 (21)	14.4 (41)
<i>Cladosporium herbarum</i> (Pers.) Link. ex Fr.	–	1.5 (1)	1.3 (1)	0.9 (2)	–	1.0 (1)	1.1 (1)	0.7 (2)
<i>Clonostachys rosea</i> f. <i>catenulata</i> (J.C. Gilman & E.V. Abbott) Schroers	–	3.0 (2)	1.3 (1)	1.4 (3)	–	1.0 (1)		0.3 (1)
<i>Clonostachys rosea</i> (Link) Schroers, Samuels, Seifert & W. Gams	–	–	–	–	1.1 (1)	–	1.1 (1)	0.7 (2)
<i>Epicoccum nigrum</i> Link	1.2 (1)	–	1.3 (1)	0.8 (2)	–	–	–	–
<i>Fusarium culmorum</i> (W.G. Smith) Sacc. *	3.7 (3)	7.5 (5)	10.6 (8)	7.1 (16)	11.8 (11)	23.6 (23)	26.5 (25)	20.6 (59)

<i>Fusarium oxysporum</i> Schlecht.	1.2 (1)	6.0 (4)	3.9 (3)	3.7 (8)	–	1.0 (1)		0.3 (1)
<i>Fusarium poae</i> (Peck.) Wollenw. *	–	4.5 (3)	2.6 (2)	2.4 (5)	–	1.0 (1)	1.1 (1)	0.7 (2)
<i>Gaeumannomyces graminis</i> (Sacc.) Arx et Olivier *	53.1 (43)	31.2 (21)	33.0 (25)	39.1 (89)	–	–	–	–
<i>Gibberella avenacea</i> R.J. Cook *	2.5 (2)	3.0 (2)	2.6 (2)	2.7 (6)	16.1 (15)	6.1 (6)	10.6 (10)	10.9 (31)
<i>Gibberella intricans</i> Wollenw.	2.5 (2)	6.0 (4)	6.6 (5)	5.0 (11)	9.7 (9)	17.4 (17)	16.0 (15)	14.4 (41)
<i>Gibberella tricineta</i> El-Gholl, McRitchie, Schoult. & Ridings	–	–	–	–	1.1 (1)	–	–	0.4 (1)
<i>Glomerella graminicola</i> D.J. Politis	–	–	–	–	26.8 (25)	7.1 (7)	5.3 (5)	13.1 (37)
<i>Haematonectria haematococca</i> (Berk. & Broome) Samuels & Rossman	2.5 (2)	9.0 (6)	5.3 (4)	5.6 (12)	7.5 (7)	13.4 (13)	6.4 (6)	9.1 (26)
<i>Microdochium bolleyi</i> (R. Sprague) de Hoog & Herm.-Nijh.	–	–	–	–	1.1 (1)	1.0 (1)	–	0.7 (2)
<i>Mucor</i> spp.	–	1.5 (1)	–	0.5 (1)	1.1 (1)	3.1 (3)	1.1 (1)	1.8 (5)
<i>Oculimacula yallundae</i> (Wallwork & Spooners) Crous & W. Gams *	–	–	–	–	1.1 (1)	2.0 (2)	–	1.0 (3)
<i>Penicillium</i> spp.	6.2 (5)	1.5 (1)	2.6 (2)	3.4 (8)	–	2.0 (2)	1.1 (1)	1.0 (3)
<i>Periconia macrospinoso</i> Lefebvre et Johnson Lefebvre et Johnson	4.9 (4)	1.5 (1)	2.6 (2)	3.0 (7)	–	–	–	–
<i>Rhizoctonia cerealis</i> van der Hoeven *	–	–	–	–	3.2 (3)	1.0 (1)	1.1 (1)	1.8 (5)
<i>Rhizoctonia solani</i> Kühn *	–	1.5 (1)	2.6 (2)	1.4 (3)	4.3 (4)	1.0 (1)	2.1 (2)	2.5 (7)
<i>Sarocladium strictum</i> (W. Gams) Summerb.	–	1.5 (1)	–	0.5 (1)	–	–	–	–
<i>Trichoderma harzianum</i> Rifai	–	1.5 (1)	1.3 (1)	0.9 (2)	–	–	–	–
<i>Trichoderma koningii</i> Oudem.	6.2 (5)	3.0 (2)	2.6 (2)	3.9 (9)	1.1 (1)	2.0 (2)	–	1.0 (3)
<i>Trichoderma polysporum</i> (Link ex Pers.) Rifai	1.2 (1)	1.5 (1)	1.3 (1)	1.3 (3)	–	1.0 (1)	–	0.3 (1)
<i>Trichoderma viride</i> Pers. ex Gray	1.2 (1)	–	1.3 (1)	0.8 (2)	3.2 (3)	4.1 (4)	3.2 (3)	3.5 (10)
Non-sporulating mycelia	4.9 (4)	–	1.3 (1)	2.1 (5)	1.1 (1)	–	1.1 (1)	0.7 (2)
Total number of isolates	81	67	76	224	93	98	94	285

* – The taxonomy of species was confirmed by applying the PCR method using species-specific SCAR primers;
In bracket number of isolates

4. DISCUSSION

The relatively great intensity of root rot symptoms could have been due to winter wheat acting as a preceding crop for barley. Barley cultivation after wheat increases the probability of fungal root infections, as indicated by previous reports [3]. *Gaeumannomyces graminis* was isolated from infected barley roots, which is considered to be the main cause of wheat root rot. A short time of cultivation of noncereal crop in the catch crop is not sufficient to reduce the population of this pathogen in soil significantly, which was confirmed in our study. Other pathogens isolated from barley, including polyphagous fungi capable of attacking not only cereals, considerably reduce the importance of the sequence of crops.

In our study, *Oculimacula* spp. and *Rhizoctonia* spp. were not the predominant pathogens isolated from the stem base in barley. It is stated that the DNA content of these pathogens in cereal tissues increases with the development of plants [27,28]. Perhaps that is the reason why in barley, with a much shorter growing season than in winter cereals, there were few symptoms, as evidenced by the low intensity of eyespot and sharp eyespot. *Oculimacula yallundae* and *R. cerealis* are characterized by slow mycelium growth and it probably did not manage to strike a stronger degree of plant tissues [28,29]. A poor severity of the disease

and the fact that these pathogens are capable of surviving for some time in soil meant that there was no significant effect of the catch crop on the fungi occurrence. The length of the growing season plays a lesser role in the rate of infection of cereals caused by *Fusarium* spp., which are characterized by a faster linear growth of mycelium, which must have been why there were observed more symptoms of infection by *Fusarium* spp. and *C. sativus*. Although the latter species is characterized by a slow growth, nevertheless, in Poland it is considered one of the main pathogens of spring barley [30]. The stem base infection with *Fusarium* spp. and *C. sativus* was significantly reduced by the cultivation of pea as the catch crop. Similarly previous studies have reported that the cultivation of catch crop can reduce the intensification of symptoms caused by these pathogens [2]. Different results, regarding the importance of catch crop, were reported by Gleń et al. [31], investigating spring wheat with bean as a catch crop. They claim that non-tillage cultivation with mulch significantly increases root rot caused by *Fusarium* spp.; in general, they report that the phytosanitary condition of cultivation with mulch was slightly better, as compared with traditional cultivation with autumn plowing.

The increase in the occurrence of powdery mildew, leaf scald and spike infection with *Fusarium* spp. and *C. sativus* in barley grown after the catch crop, as compared with control, could have been a result of the increased density of sowing. Barley cultivated in soil after pea made the stems and spikes closer to each other, which greatly facilitates the spread of pathogens that cause those diseases, as reported by Walters et al. [7]. According to Jensen and Munk [32], the use of catch crop may increase the infection due to the accumulation of nitrogen in soil. Plowed biomass of field pea contains a lot of nitrogen, which can later be used by barley as indicated by Porta-Puglia and Aragona [33]. According to Newton et al. [34] and Walters et al. [7], barley heavily fertilized with nitrogen is more susceptible to infections caused by *B. graminis* and *R. secalis*. A higher plant density may also indirectly contribute to the severity of disease, including changes in the sowing microclimate. Usually, the temperature in the dense sowing is more uniform, there is a relatively higher humidity, and water remains on the leaves for a longer time, which greatly favors the fungal infection of plants by fungal pathogens [7,35].

The opposite results were obtained for leaf rust, for which most of the symptoms were noted in barley grown without catch crop. However, the first symptoms of the disease appeared late, when a large surface of the leaf was struck by other pathogens. *Puccinia hordei*, a biotrophic fungal pathogen, mainly affects the places where tissues are healthy, allowing a rapid development of the pathogen [7,36]. Due to the lower surface of the leaves, which could be infected, the development of the pathogen was significantly reduced. A similar trend is also observed for infection caused by *B. graminis* [36], however, in our experiment the pathogen occurred much earlier, before the development of other diseases symptoms. According to Walters et al. [7] and Bingham et al. [35], a high density may also hinder the spread of spores of *P. hordei* since barley grown after pea observed a decrease in the severity of rust.

5. CONCLUSION

Catch crop has an ambiguous effect on the health of barley. Although it significantly decreased the stem base infection with *Fusarium* spp. and *Cochliobolus sativus* and leaf infection with *P. hordei*, it also increased the leaf infection with *B. graminis* and *R. secalis* and spike infestation with *Fusarium* spp. and *C. sativus*.

The pathogenic fungi isolated from spring barley roots were mostly represented by *Gaeumannomyces graminis* and from stem bases – with *Fusarium* spp., especially *F. culmorum*. There were also found many *C. sativus* and *Glomerella graminicola* isolates.

The pathogens occurring on necrotic spots on spikelets in spring barley were mostly represented by *C. sativus* and less frequently by *Fusarium* spp.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

AUTHORS' CONTRIBUTIONS

This work was carried out in collaboration between all authors. Author GL wrote the manuscript, performed analysis of plant health, isolation and identification of fungi, performed the statistical analysis. Author EW designed and carried out the field experiment. All authors have read and approved the final manuscript.

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