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THE HEALTH STATUS OF WINTER WHEAT CV. ZYTA DEPENDING ON THE APPLIED AGROTECHNOLOGY

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Abstract. Winter wheat cv. Zyta was grown in organic and integrated farming systems as part of a field experiment conducted in north-eastern Poland in 2008-2010. The aim of the study was the assessment of the effect of different farming systems and various protective treatments on plant health status. The severity of infections caused by *Septoria* spp., *Blumeria graminis* and *Puccinia recondite,* affecting the leaves of winter wheat plants, was determined mainly by weather conditions and the applied cultivation system. 2009 was a rainy year which supported the development of Septoria diseases, whereas the dry year 2010 was favourable for the growth of powdery mildew of grasses and cereals. The leaves of winter wheat plants grown in the organic farming system were more often infected with brown rust, whereas plants grown in two variants of the integrated farming system were more likely to be affected by Septoria diseases and powdery mildew. The severity of stem-base diseases varied depending on the year of the study and the applied forecrop. The highest infection rates were reported when winter wheat was grown as a forecrop. The rainy year 2009 stimulated the development of stem-base diseases. The positive effect of EM biopreparation on the health status of winter wheat was observed only in the organic farming system.

Key words: Effective Microorganisms, integrated farming system, organic farming system, plant disease

INTRODUCTION

In moderate climate zones, diseases affecting the leaves and ears of wheat plants are caused mostly by *Mycosphearella graminicola* (Fuckel) Schroeter (anamorph *Septoria tritici* Rob. Ex Desm.), *Phaeosphaeria nodorum* (E. Müller) (anamorph *Stagonospora nodorum* Berk.), *Blumeria graminis* (DC) Speer and *Puccinia recondita* f. sp. *tritici* Rob. ex. Desm [Leroux *et al.* 2007, Perelló *et al.* 2009, Nowara *et al.* 2010]. The

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predominant stem-base diseases of winter wheat which significantly reduce crop yields are Fusarium foot rot and eyespot [Ray *et al.* 2006]. Toxin-producing species of the genus Fusarium pose the greatest threat to wheat ears, thus decreasing yield quality [Magan *et al.* 2006, Peterson and Lima 2010, Stępień and Chełkowski 2010, Mankevičiené *et al.* 2011]. Under circumstances favourable for pathogen growth, synthetic plant protection products are used to control crop diseases. Excessive use of chemical products may, however, support the development of pathogens resistant to the applied treatments [Mavroeidi and Shaw 2005, Leroux *et al.* 2007, Torriani *et al.* 2008]. Thus, it is necessary to search for alternative methods of plant cultivation and protection which would limit the use of fertilizers and crop protection chemicals [Perello *et al.* 2009]. Such techniques are offered by organic farming which relies on legume-based crop rotations and intercrops. Crops are also supplied with organic and mineral fertilizers. Weeds are controlled mechanically, and pathogenic infections are prevented with the use of biocontrol agents or products containing sulphur and copper compounds. The aim of organic farming is to put an end to environmental degradation, and produce foods with superior sensory attributes and a high nutritive value. Organic farming has completely different needs than other forms of agricultural production. One of the challenges faced by organic farmers is the limited availability of biological growth promoters and naturally derived pesticides and fungicides on the market [Perello *et al.* 2009].

The Effective Microorganisms (EM) biocontrol agent is a registered, patented product on the Polish market, intended for soil application. It contains a blend of five microbial groups: yeast-like fungi (*Saccharomyces cerevisiae*, *Candida utilis*), fungi used in fermentation (*Aspergillus oryzae*, *Mucor hiemalis*), *Actinomycetes* (*Streptomyces albus*, *S. griseus*) and groups of bacteria that remain in biological equilibrium including lactic acid bacteria (*Lactobacillus plantarum*, *L. casei*, *Streptoccocus lactis*) and photosynthetic bacteria (*Rhodopseudomonas palustrus*, *Rhodobacter spaeroides*) [Higa 1997]. The exact composition and proportions of ingredients in the EM inoculant remain unknown. The product combines 80 species of coexisting microorganisms which were selected from a group of 2000 species isolated from various environments [Higa and Parr 1995, Higa 1997].

Experiments carried out in Poland revealed that the use of EM leads to only a minor improvement in plant yield and health status [Okorski and Majchrzak 2007, Boligłowa and Gleń 2008, Okorski *et al.* 2008, Górski and Góra 2009, Górski and Kleiber 2010]. When applied under field conditions, the examined product failed to effectively protect cereal crops against steam-base diseases [Waleryś 2005, Boligłowa and Gleń 2008], leaf infections caused by *Drechslera tritici-repentis*, and fungal ear infections caused by Stagonospora nodorum [Boligłowa and Gleń 2008]. The severity of *Puccinia recondita* and *Stagonospora nodorum* [Boligłowa and Gleń 2008] infections attacking the leaves of winter wheat plants under field conditions was significantly reduced only in one year of the study. The observed increase in the yield of winter wheat treated with the EM microbial inoculant was small and statistically non-significant [Piskier 2006]. Despite a limited number of studies and contradictory results, the EM product is advertised in nearly all regions of the world as an agent which offers a host of benefits [Mayer *et al.* 2010, Abdullah *et al.* 2011]. The objective of the field experiment was the assessment of the effect of different farming systems and various protective treatments on plant health of winter wheat plants.

MATERIAL AND METHODS

Field experiment

The health status of winter wheat cv. Zyta was evaluated in a field experiment conducted in 2008-2010 in Bałycyny, Poland (53°35' N; 19°51' E). The experimental factors were four six-field crop rotations: two in the organic farming system (variants A and B) and two in the integrated system (variants C and D). The following crop rotation scheme was applied in organic farming system A: 1) potato, 2) spring barley with undersown alfalfa and red clover, 3) alfalfa and red clover, 4) alfalfa and red clover, 5) winter wheat intercropped with phacelia, 6) oats intercropped with mustard and B: 1) potato, 2) spring barley with undersown red clover, 3) red clover, 4) potato, 5) winter wheat, 6) winter rye intercropped with white mustard. Manure (30 $Mg \cdot ha^{-1}$) was applied only to potatoes, and no mineral fertilizers were used (Table 1). Weeds were controlled mechanically (harrowing conducted twice in the spring). In an organic farming system B, manure was applied to potatoes at 15 $Mg \cdot ha^{-1}$.

In an integrated farming system C, winter wheat was supplied with mineral fertilizers according to standard requirements. The following crop rotation scheme was applied: 1) potato, 2) winter wheat, 3) spring barley with undersown red clover, 4) red clover, 5) winter wheat, 6) winter rye. Manure (30 $Mg \cdot ha^{-1}$) was applied to potatoes. Diseases and weeds were controlled with fungicides and herbicides at the rates recommended by manufacturers. Winter wheat plants were treated with Alert 375 SC fungicide (flusilazole, carbendazim) at the first node stage (BBCH 31). In an integrated farming system D (high-input), winter wheat was supplied with mineral fertilizers with nitrogen and potassium content 50% higher than in variant C. The crop rotation scheme in variant D was as follows: 1) potato, 2) winter wheat, 3) oats, 4) potato, 5) winter wheat, 6) winter wheat. Fungicides were applied twice: Alert 375 SC (flusilazole, carbendazim) at the first node stage (BBCH 31) and Opera Max 147.5 SE (pyraclostrobin, epoxiconazole) at the ear formation stage (BBCH 55). Growth regulators Moddus 250 EC (trinexapac ethyl) were also used. Manure (30 $Mg \cdot ha^{-1}$) was applied to potatoes once per rotation.

The surface area of a crop rotation field was 100 m^2. The experiment was performed in a randomized block design, in three replications. It was established on proper grey-brown podsolic soil developed from light silty loam underlain by heavy loamy sand. Winter wheat was grown in accordance with standard cultivation requirements for north-east Poland. Temperatures and rainfall at the experimental site from 2007 to 2010 are presented in Table 2. During the experiment, the winters were mild. In the growing season each year, July was the warmest month. In 2008 the growing season was characterized by an insignificant rainfall (from April to July rainfall was not greater than 50 mm). April 2009 and 2010 was a period of drought. Heavy rainfall was recorded in June 2009 and May 2010.

EM microbial inoculant

In an organic farming system B and conventional farming system D, EM was applied once to soil before sowing winter wheat, and twice to leaves in the spring (BBCH 22, BBCH 55). The EM preparation was applied at the recommended dose of 20 $dm^{-3} \cdot ha^{-1}$.

Table 1. Basic data of winter wheat agrotechnology
Tabela 1. Podstawowe dane agrotechniczne pszenicy ozimej

Agrotechnological elements Elementy agrotechniki	Cultivation system – System uprawy			
	organic – ekologiczne		integrated – integrowny	
	A	B	C	D
Seeds per 1 ha Nasion na 1 ha	550	550	500	500
Fertilization Nawożenie $kg \cdot ha^{-1}$	not applied nie stosowano	not applied nie stosowano	P – 26 K – 83 N – 60 + 30 + 30	P – 26 K – 125 N – 90 + 45 + 45
Manure – Obornik $Mg \cdot ha^{-1}$	30	15 + 15	30	30
Effective microorganisms EM Efektywne mikroorganizmy EM $dm^3 \cdot ha^{-1}$	not applied nie stosowano	applied stosowano (20 + 20 + 20)	not applied nie stosowano	applied stosowano (20 + 20 + 20)
Weed control Odchwaszczanie	harrowing bronowanie	harrowing bronowanie	Cougar 600 SC (diflufenican, isoproturon) Huzar Activ 387OD (iodosulfuron-methyl-sodium, 2,4-D)	Cougar 600 SC (diflufenican, isoproturon) Huzar Activ 387OD (iodosulfuron-methyl-sodium, 2,4-D)
Pathogen protection Ochrona przed patogenami	not applied nie stosowano	not applied nie stosowano	Alert 375 SC (flusilazole, carbendazim)	Alert 375 SC (flusilazole, carbendazim) Opera Max 147,5 SE (pyraclostrobin, epoxiconazole)

Stem-base, leaf and ear health

The health status of lower leaves was evaluated at the stage of inflorescence emergence (BBCH 51). The incidence of flag leaf diseases was evaluated at the dough stage (BBCH 87) of winter wheat grain on 100 leaves randomly selected in each treatment. The severity of Septoria tritici blotch, powdery mildew and brown rust was determined. Leaves with single spots were considered to be mildly infected (1% of leaf area affected). In more severely affected leaves, the percentage area showing symptoms of the above diseases was determined. The average infected area was determined on flag leaves. The percentage of green leaf area was calculated at the dough stage (BBCH 87) of winter wheat grain on 100 flag leaves. The severity of ear infections caused by pathogens of the genera *Fusarium* and *Septoria* was evaluated at the dough stage. The average percentage of ear area infected by the analyzed pathogens was determined.

At the watery ripe stage (BBCH 71) and full ripeness stage (BBCH 92), 100 winter wheat culms were randomly collected from each treatment. Leaf sheaths were removed at the laboratory, and the health of culms was evaluated on a four-point scale. Culms with single spots were considered to be mildly infected (1^o), culms with lesions covering up to 50% surface area were considered to be moderately infected (2^o), and culms with lesions covering more than 50% surface area were considered to be severely infected (3°). The most severely infected leaves had rotten, damaged tissues (4°). The average degree of stem infection was determined.

Statistical analysis

An analysis of variance (ANOVA) was performed using Statistica 9.0 software. The significance of differences between means from the field was estimated by Duncan's test ($p = 0.05$).

Table 2. Temperature and rainfall at the site and time of experiments
Tabela 2. Temperatura i opady w miejscu i okresie prowadzenia badań

Month – Miesiąc	Temperature – Temperatura, °C				Rainfall – Opady, mm			
	2007	2008	2009	2010	2007	2008	2009	2010
January – styczeń	–	0.9	-3.7	-8.9	–	30.8	16.2	13.3
February – luty	–	2.3	-1.5	-2.9	–	33.9	17.7	14.2
March – marzec	–	2.9	1.9	2.1	–	47.1	68	23.8
April – kwiecień	–	7.7	9.7	7.9	–	33.8	3.7	9.4
May – maj	–	12.3	12.2	12.0	–	48.4	89.6	105.5
June – czerwiec	–	16.5	14.7	15.7	–	27.8	133.1	73.7
July – lipiec	–	18.3	19.9	20.8	–	47.0	82.2	87.8
August – sierpień	–	17.7	18.5	19.3	–	103.1	25.7	99.3
September – wrzesień	12.6	11.9	14.7	12.2	65.4	17.0	15.6	45.0
October – październik	7.4	8.6	5.9	–	48.9	104.6	58.5	–
November – listopad	1.0	4.0	5.2	–	50	40.5	40.8	–
December – grudzień	0.4	-0.2	-1.7	–	25.2	29.4	29.6	–

RESULTS

In all years of the experiment, winter wheat leaves were infected mostly by *Septoria* spp. (Table 3-6). In 2008, at the stage of inflorescence emergence, the average severity of Septoria diseases on lower leaves was significantly higher (7.7%) than in 2010 (38.7%). In the second year of the study, bottom leaves were dried up, and they were not analyzed on the first sampling date. Septoria tritici blotch developed most rapidly in 2009 when the disease affected 62.9% of flag leaf area on average at the flowering stage. The severity of Septoria tritici blotch was significantly affected by the crop rotation scheme and the application of EM only in 2009. Symptoms of the disease were considerably less prevalent on flag leaves of winter wheat plants grown in the organic farming system A in comparison with an organic farming variant B, where plants were treated with EM (Table 3, 4). Forecrop and crop rotation schemes affected the health status of flag leaves. In the second year of the study, flag leaves of winter wheat plants grown after red clover in crop rotation C were significantly more infected than plants grown after potatoes (Table 5).

Symptoms of the disease caused by *Blumeria graminis* pathogens were observed on flag leaves mainly in 2010. Powdery mildew infections were sporadically noted in the remaining years of the study. In 2010, the severity of powdery mildew infections in the organic farming system B involving EM, was 2.42 times lower in comparison with the organic variant A, where the above agent was not used (Table 3, 4). In conventional farming systems C and D, EM had no significant inhibitory effect on the severity of *Blumeria graminis* infection (Table 5, 6).

Symptoms of brown rust (*Puccinia recondita*) were observed mainly in the first year of the study in the organic farming system A, where disease severity reached 8.6% (Table 3). In the organic farming system B with the EM inoculant, the prevalence of brown rust infections on flag leaves was 4.5-fold lower in comparison with system A (Table 3, 4).

Flag leaf infections reduced green leaf area. A strong correlation was reported between the severity of Septoria tritici blotch and leaf greenness. Owing to variations in the rate of flag leaf infections, the above parameter slightly differentiated the health status of plants grown in the crop rotation systems compared in the study. On average, the largest green leaf area was observed in winter wheat plants grown in crop rotations B and C, where red clover was grown as a forecrop.

At the milk ripe stage, winter wheat ears were generally weakly infected by pathogens of the genera *Septoria* and *Fusarium*. Symptoms of Septoria glume blotch were more intensified only in the second year of the study, and the severity of the disease in the organic farming system A was significantly lower in comparison with the remaining treatments (Table 3-6). The farming system had no significant effect on the severity of *Fusarium* head blight.

At the stem-base, winter wheat plants were affected mostly by eyespot (*Oculimacula* spp.), whereas symptoms of *Fusarium* foot rot (*Fusarium* spp.) and sharp eyespot (*Rhizoctonia* spp.) were less frequently observed (Table 3-6). Signs of foot rot (*Gaeumannomyces graminis*) were reported on wheat culms only in 2009. Eyespot severity reached the highest level in the third year of the experiment. In 2009, disease prevalence was high at the stage of inflorescence emergence, but the epidemic declined by the time wheat grain reached the full ripeness stage. On the first observation dates in 2008 and 2010, eyespot infections were not severe, but the disease developed rapidly with plant growth until the stage of full ripeness, in particular in the third year of the study. The farming system and the use of EM had no significant influence on the incidence of stem-base diseases. Stem-base health was determined mainly by the type of forecrop. Winter wheat plants grown after winter wheat and potatoes were generally more severely affected by stem-base diseases caused by pathogens of the genus *Oculimacula* than plants cultivated after legumes. Symptoms of *Fusarium* foot rot were observed in 2008 and 2009, but disease severity was relatively low in the first year of the study. In most wheat plants grown after winter wheat, the severity of *Fusarium* foot rot was significantly higher in comparison with other treatments.

Table 3. Severity of leaf, ear and stem-base infections in winter wheat grown in the organic system A after red clover
Tabela 3. Nasilenie chorób liści, kłosów i podstaw źdźbeł pszenicy ozimej rosnącej w systemie ekologicznym A po koniczynie czerwonej

Year Rok	Health status of leaves Zdrowotność liści				Percentage of green leaf area Procent zielonej powierzchni liści	Health status of spikes Zdrowotność kłosów		*Oculimacula* spp.		*Fusarium* spp.		*Rhizoctonia* spp.	
	lower dolnych	flag – flagowych						BBCH 65	BBCH 92	BBCH 65	BBCH 92	BBCH 65	BBCH 92
	Septoria spp.	*Septoria* spp.	*Blumeria graminis*	*Puccinia recondita*		*Septoria* spp.	*Fusarium* spp.						
	percentage of leaf area infected by pathogens procent powierzchni liści porażonej patogenami					percentage of ear area infected by pathogens procent powierzchni porażonej patogenami		average degree of stem-base infection średni stopień porażenia podstawy źdźbła					
2008	6.2 *a*	2.18 *b*	0.00 *b*	8.6 *a*	61.9 *b*	0.00 *b*	0.00 *b*	0.53 *b*	1.69 *c*	0.5 *a*	0.25 *b*	0.00	0.02
2009	nt	48.9 *a*	0.28 *b*	0.00 *c*	16.08 *c*	4.53 *a*	0.06 *a*	2.2 *a*	2.34 *b*	0.34 *b*	1.17 *a*	0.00	0.06
2010	nt	7.3 *ab*	7.41 *a*	1.03 *b*	82.33 *a*	1.24 *b*	0.00 *b*	0.76 *b*	3.08 *a*	0.00 *c*	0.00 *bc*	0.00	0.00

values with the same letters in columns do not differ significantly (p = 0.05) according to Duncan's test – wartości oznaczone tymi samymi literami nie różnią się istotnie w kolumnach według testu Duncana (p = 0,05)
nt – not tested – nie testowano

Table 4. Severity of leaf, ear and stem-base infections in winter wheat grown in the organic system B after potato
Tabela 4. Nasilenie chorób liści, kłosów i podstaw źdźbeł pszenicy ozimej rosnącej w systemie ekologicznym B po ziemniaku

Year Rok	Health status of leaves Zdrowotność liści				Percentage of green leaf area Procent zielonej powierzchni liści	Health status of spikes Zdrowotność kłosów		*Oculimacula* spp.		*Fusarium* spp.		*Rhizoctonia* spp.	
	lower dolnych	flag – flagowych						BBCH 65	BBCH 92	BBCH 65	BBCH 92	BBCH 65	BBCH 92
	Septoria spp.	*Septoria* spp.	*Blumeria graminis*	*Puccinia recondita*		*Septoria* spp.	*Fusarium* spp.						
	percentage of leaf area infected by pathogens procent powierzchni liści porażonej patogenami					percentage of ear area infected by pathogens procent powierzchni porażonej patogenami		average degree of stem-base infection średni stopień porażenia podstawy źdźbła					
2008	6.40 *b*	0.63 *c*	0.17 *b*	1.88 *a*	89.90 *a*	0.00 *b*	0.00 *b*	1.68 *b*	1.34 *c*	0.29 *b*	0.10 *b*	0.00	0.00 *b*
2009	nt	67.23 *a*	0.45 *b*	0.00 *b*	8.35 *b*	8.04 *a*	0.23 *a*	1.86 *a*	2.35 *b*	0.58 *a*	0.65 *a*	0.00	0.26 *a*
2010	37.30 *a*	7.00 *b*	3.06 *a*	1.33 *a*	83.00 *a*	1.24 *b*	0.00 *b*	1.50 *b*	2.98 *a*	0.00 *c*	0.00 *c*	0.00	0.00 *b*

values with the same letters in columns do not differ significantly (p = 0.05) according to Duncan's test – wartości oznaczone tymi samymi literami nie różnią się istotnie w kolumnach według testu Duncana (p = 0,05)

Table 5. Severity of leaf, ear and stem-base infections in winter wheat grown in an integrated system C
Tabela 5. Nasilenie chorób liści, kłosów i podstaw źdźbeł pszenicy ozimej rosnącej w systemie integrowanym C

Field number (forecrop)	Year Rok	Health status of leaves Zdrowotność liści: lower dolnych				Percentage of green leaf area Procent zielonej powierzchni liści	Health status of spikes Zdrowotność kłosów		*Oculimacula* spp.		*Fusarium* spp.		*Rhizoctonia* spp.	
			flag – flagowych						BBCH 65	BBCH 92	BBCH 65	BBCH 92	BBCH 65	BBCH 92
		Septoria spp.	*Septoria* spp.	*Blumeria graminis*	*Puccinia recondita*		*Septoria* spp.	*Fusarium* spp.						
		percentage of leaf area infected by pathogens procent powierzchni liści porażonej patogenami					Percentage of ear area infected by pathogens procent powierzchni porażonej patogenami		average degree of stem-base infection średni stopień porażenia podstawy źdźbła					
C 2 (Red clover)	2008	11.42 *b*	0.6 *d*	0.15 *b*	0 *b*	81.31 *a*	0 *c*	0 *c*	0.97 *ab*	1.69 *c*	0.63 *b*	0.11 *c*	0.00	0 *c*
	2009	nt	68.31 *a*	0.42 *b*	0 *b*	8.35 *d*	8.03 *b*	0.23 *a*	1.20 *a*	2.17 *b*	0.24 *c*	1.15 *a*	0.00	0.42 *b*
	2010	38.45 *a*	9.56 *c*	4.41 *a*	0.67 *a*	74.33 *a*	1.24 *c*	0 *c*	0.68 *b*	3.11 *a*	0 *de*	0 *c*	0.00	0 *c*
C 5 (Potato)	2008	4.9 *b*	1.42 *d*	0.88 *b*	0.003 *b*	83.09 *a*	0 *c*	0 *c*	0.97 *ab*	2.65 *ab*	1.1 *a*	0.5 *bc*	0.00	0 *c*
	2009	nt	51.76 *b*	0.85 *b*	0.2 *ab*	18.86 *c*	12.48 *a*	0.15 *bc*	1.57 *a*	1.67 *c*	0.12 *d*	0.99 *ab*	0.00	0.64 *a*
	2010	40.41 *a*	11.67 *c*	3.5 *a*	1 *a*	69.76 *b*	1.96 *bc*	0 *c*	0.74 *b*	3.66 *a*	0 *de*	0 *c*	0.00	0 *c*

values with the same letters in columns do not differ significantly (p = 0.05) according to Duncan's test – wartości oznaczone tymi samymi literami nie różnią się istotnie w kolumnach według testu Duncana (p = 0,05)

Table 6. Severity of leaf, ear and stem-base infections in winter wheat grown in the integrated system D
Tabela 6. Nasilenie chorób liści, kłosów i podstaw źdźbeł pszenicy ozimej rosnącej w systemie integrowanym D

Field number (forecrop)	Year Rok	Health status of leaves Zdrowotność liści – lower dolnych: *Septoria* spp.	Health status of leaves – flag – flagowych: *Septoria* spp.	flag – flagowych: *Blumeria graminis*	flag – flagowych: *Puccinia recondita*	Percentage of green leaf area Procent zielonej powierzchni liści	Health status of spikes Zdrowotność kłosów: *Septoria* spp.	Health status of spikes: *Fusarium* spp.	*Oculimacula* spp. BBCH 65	*Oculimacula* spp. BBCH 92	*Fusarium* spp. BBCH 65	*Fusarium* spp. BBCH 92	*Rhizoctonia* spp. BBCH 65	*Rhizoctonia* spp. BBCH 92
		percentage of leaf area infected by pathogens procent powierzchni liści porażonej patogenami					percentage of ear area infected by pathogens procent powierzchni porażonej patogenami		average degree of stem-base infection średni stopień porażenia podstawy źdźbła					
C 2 (Red clover)	2008	10.42 *b*	1.19 *d*	0.05 *c*	0 *c*	82.35 *a*	0 *c*	0 *c*	1.07 *b*	2.2 *c*	0.63 *b*	0.26 *b*	0	0 *b*
	2009	nt	78.5 *a*	0.67 *c*	0 *c*	3.9 *d*	6.56 *ab*	0.23 *a*	1.09 *b*	1.6 *d*	0.31 *c*	1.77 *a*	0	0.38 *a*
	2010	44.77 *a*	12.33 *c*	6.59 *a*	0.67 *b*	64,0 *b*	1.16 *b*	0 *c*	1.13 *b*	3.39 *a*	0 *d*	0 *c*	0	0 *b*
C 5 (Potato)	2008	nt	0.8 *d*	0 *c*	0 *c*	71.13 *b*	0 *c*	0 *c*	0.67 *d*	2.68 *b*	0.37 *c*	0 *c*	0	0 *b*
	2009	nt	57.01 *c*	0.63 *c*	0 *c*	18.86 *c*	6.56 *ab*	0.15 *b*	2.08 *a*	2.09 *c*	0 *d*	1.72 *a*	0	0.09 *a*
	2010	nt	11.25 *c*	0.00 *c*	1.67 *a*	69.78 *b*	1.16 *b*	0 *c*	0.73 *cd*	2.37 *bc*	0 *d*	0 *c*	0	0 *b*
D 6 (Winter wheat)	2008	7.28 *b*	1.23 *d*	0.04 *c*	0.003 *c*	71.15 *b*	0 *c*	0 *c*	1.03 *b*	1.91 *d*	0.8 *a*	0.06 *c*	0	0 *b*
	2009	nt	70.27 *a*	0.33 *c*	0 *c*	2.89 *d*	9.76 *a*	0.05 *c*	2.08 *a*	2.11 *c*	0.6 *b*	1.64 *a*	0	0.25 *a*
	2010	34.88 *a*	8.56 *c*	3.39 *b*	0.67 *b*	87.67 *a*	1.24 *b*	0 *c*	1.5 *cd*	3.52 *a*	0 *d*	0 *c*	0	0 *b*

values with the same letters in columns do not differ significantly (p = 0.05) according to Duncan's test – wartości oznaczone tymi samymi literami nie różnią się istotnie w kolumnach według testu Duncana (p = 0,05)

DISCUSSION

In the present experiment, winter wheat plants were most severely infected in 2009 which was characterized by a drought in spring, heavy rainfall in May and June, and an average temperature of 20°C in July. The winter of 2008/2009 was mild with a minimum temperature of 5°C. The above conditions are optimal for the growth of pathogens of the genus *Septoria* [Mirzwa-Mróz *et al*. 2005]. In 2009, at the stage of inflorescence emergence, lower leaves of winter wheat plants were dried up, and the prevalence of Septoria diseases continued to be high until the stage of full grain ripeness. Pathogenic changes affected up to 78.5% of leaf surface area. Air humidity and temperature had a decisive impact on Septoria disease progression. Their values and distribution were analyzed and described in a model of wheat leaf diseases [Shah *et al.* 1995, Audsley *et al.* 2006]. The severity of Septoria diseases was significantly lower in the organic farming system A due to lower plant density and a lower moisture content in leaves. The remaining factors, including forecrop, had no significant effect on the incidence of Septoria leaf spot.

Symptoms of brown rust were noted mostly in the organic farming system in the first year of study. The winter of 2007/2008 was mild with temperatures above zero, and large quantities of pathogen inoculum surviving in soil. In comparison with the conventional farming system, the moisture content in wheat grown in the organic farming system was more favourable for the proliferation of *Puccinia recondita* pathogens. June and July were dry months, and lower plant density in the organic farming system additionally supported the development of brown rust. The incidence of brown rust was lower in the organic farming system with the EM microbial inoculant than in the organic system without EM only in the first year of the study. Our findings confirmed the results of the study in which EM had no repeatable protective effect on field-grown potatoes [Mayer *et al.* 2010].

The EM inoculant had a limited effect on field-grown crops. The analyzed product significantly influenced only the plants grown in the organic farming system. In 2009, EM reduced the symptoms of infections caused by *Puccinia recondita* on flag leaves, and the symptoms of stem-base diseases caused by *Fusarium* fungi. In 2010, the symptoms of infection caused by *Blumeria graminis* on flag leaves of wheat plants grown in the organic system and treated with EM were less extensive than the symptoms of powdery mildew of grasses and cereals in treatments where the biocontrol agent was not applied. The results of other studies also point to the limited efficacy of effective microorganisms [Boligłowa and Gleń 2008, Mayer *et al.* 2010]. The above could be attributed to the unstable composition of microorganisms contained in the product, which was described by Van Vliet *et al.* [2006]. The above authors found that quantity of bacterial DNA differed across batches of EM1. The low effectiveness of EM could also be explained by low survival rates of constituent bacteria in soil [Wachowska *et al.* 2011], which probably constitute a food source for other soil-dwelling microbes. According to the manufacturer, EM's mechanism of action is based on the competition for food between microorganisms, antagonism and hyperparasitism [Higa 1997]. The suggested mechanism is, however, unlikely to be observed in a field environment because the number of microorganisms in the product is significantly lower than the abundance of soil microbial communities, therefore, their ability to survive in a soil environment seems rather illusive [Mayer *et al.* 2010, Wachowska *et al.* 2011].

CONCLUSIONS

The health status of winter wheat leaves was determined mainly by weather conditions and the applied farming system. The rainy year 2010 contributed to the severity of Septoria diseases. Plants grown in the organic farming system were affected mainly by brown rust, whereas the symptoms of Septoria diseases and powdery mildew of grasses and cereals were more frequently observed in conventional farming systems (integrated and high-input systems). The severity of stem-base diseases varied depending on the year of the study and the applied forecrop. Winter wheat was the least desirable forecrop. The product's beneficial effect on plant health was negligible, and only sporadically observed in the field experiment.

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ZDROWOTNOŚĆ PSZENICY OZIMEJ ODMIANY ZYTA W ZALEŻNOŚCI OD STOSOWANEJ AGROTECHNOLOGII

Streszczenie. W latach 2008-2010 w północno-wschodniej Polsce uprawiano pszenicę ozimą odmiany Zyta w systemie ekologicznym i integrowanym. Celem badań była ocena wpływu płodozmianów, agrotechniki i zabiegów ochronnych na zdrowotność roślin. Nasilenie infekcji liści pszenicy ozimej wywołanych przez *Septoria* spp., *Blumeria graminis* i *Puccinia recondite* uzależnione było od warunków atmosferycznych i zastosowanego systemu uprawy. Rok 2009 był deszczowy, co sprzyjało rozwojowi septoriozy, natomiast suchy 2010 rok sprzyjał rozwojowi mącznika prawdziwego zbóż i traw. Liście pszenicy ozimej uprawianej w systemach ekologicznych częściej wykazywały objawy rdzy brunatnej, w dwóch wariantach systemu integrowanego były bardziej narażone na infekcje patogenami powodującymi septoriozy i mącznika prawdziwego. Nasilenie chorób podstawy źdźbła było zróżnicowane w latach badań i uzależnione od przedplonu. Najwyższe wskaźniki zachorowalności odnotowano w przypadku, gdy pszenicę ozimą uprawiano po pszenicy. Deszczowy rok 2009 przyczynił się do rozwoju chorób podstawy źdźbła. Pozytywny wpływ biopreparatu EM na zdrowotność pszenicy ozimej stwierdzono tylko w systemach uprawy ekologicznej.

Słowa kluczowe: choroby pszenicy ozimej, efektywne mikroorganizmy, ekologiczny i integrowany system uprawy

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