

Root and Foot Rot Diseases of Winter Wheat Grown in Conventional and Organic Systems

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Abstract

The object of the study was fungous diseases occurring on roots, leave sheaths and stem base of winter wheat in the two opposing cropping systems (organic and conventional). The observations were made in vegetation periods (2007-2009) in the fields of winter wheat in northern Poland. Every year on each plot of compared farming systems root rot occurred (*Fusarium* spp., *Gaeumannomyces graminis* and other fungi). For the period of 3 years the degree of disease injury on the roots of winter wheat grown in the conventional system in the vegetation period increased, while in the organic one remained on pretty the same level. On average a lot more affected roots, especially in the flowering stage, occurred on the winter wheat grown in the conventional system. *Fusarium* foot rot (*Fusarium* spp.) developed on the wheat during the entire vegetation period. It was the most dangerous root and foot rot disease (the highest indexes of injury). The mean degree of disease injury on leave sheath was on pretty the same level in the two farming systems, although in investigated vegetation periods differed a lot, whereas at the bases of stems the pathogen was on the higher level on the wheat in the conventional system. Also eyespot (*Tapesia yallude*) developed in the entire vegetation period of the winter wheat, but its intensity was much lower than in case of fusarium foot rot. Leave sheaths of the wheat grown in the conventional system were slightly stronger affected than those grown in the organic system. In the flowering stage the intensity of the disease in both farming systems became equal, while in the wax maturity it was considerably higher in the conventional system. Sharp eyespot (*Rhizoctonia* spp.) appeared relatively late and occurred only in two years of investigation. The intensiveness of the disease was definitely higher on the organic plots. Among the affected roots, taken in the stem elongation stage, from the organic system 28 cultures of fungi were isolated, and from the conventional one 24 colonies. Cereals pathogenic fungi amounted 35.8% of isolates obtained from the organic system and as many as 66.7% from the conventional system. Among the affected roots, taken in the flowering stage, from the organic system 68 cultures of fungi were isolated in all, and from the conventional one 25 colonies. Cereals pathogenic fungi amounted 38.2% of isolates obtained from the organic system and 56.0% from the conventional system. Among the affected stem bases, taken in the wax maturity stage, from the organic system 56 cultures of fungi were isolated in all, and from the conventional one 52 colonies. Cereals pathogenic fungi amounted 48.4% of isolates obtained from the organic system and 53.6% from the conventional system. In the case of all root and foot rot diseases of wheat grown in the organic system, an advantageous influence of greater biodiversity and number of various fungi species living in root proximity was noticed as opposed to the conventional system.

Keywords

Winter Wheat, Root and Foot Rot Diseases, Organic Farming, Conventional, Farming

1. Introduction

The root and foot rot diseases are considered the most dangerous among the diseases caused by pathogens connected with the soil environment [1] [2]. Their common feature is a patch occurrence in productive fields, leading to the shortening vegetation of crops and yield decrease [1] [3]-[5]. The occurrence of the root and foot rot diseases strengthens as a result of the simplification of crop rotations, which happens in the conventional system of cereals growing [6]-[8]. In order to counteract these disadvantageous phenomena a range of fungicides is applied, which decrease the pressure of fungi on roots and stem base [9]-[14]. Cereals cropping in the organic system, on the other hand, is closely related to a proper crop rotation and manuring, which due to the increase of biomass and biodiversity of microorganisms in soil, should protect crops to a high degree against attacks of pathogens living in soil [15].

The aim of the study was to evaluate the effect of organic and conventional growing method on the occurrence of root and foot rot diseases and to learn about the species content of pathogens living in the above-mentioned organs.

2. Materials and Methods

The object of the study was fungous diseases occurring on roots, leave sheaths and stem base of winter wheat in the two opposing cropping systems (organic and conventional). The observations of the health state were made in three successive vegetation periods (2007-2009) in the productive fields of winter wheat of the *Korweta* variety. Organic winter wheat growing was conducted on a family farm in Kurzętnik (between Olsztyn and Toruń), which is run in the organic system since 1998 and certified since 2000. The comparison was made with the conventional farm in Łasin (in 20 km distance) run in a very intensive way, with high doses of mineral fertilizers and chemical plant protection agents.

For the study productive plantations were chosen covering 5 - 38 ha each. In order to eliminate the natural variation of soil quality, small plots of the size of 40 by 60 meters were selected by a soil scientist on each plantation. Thanks to it the chosen plots were of the same soil quality. According to soil quality evaluation, the plots dispose brown loamy soil (containing 28% - 30% particles of less than 0.02 mm diameter). The humus content was between 1.5% and 1.7% and soil reaction was neutral (pH 6.3 to 7.0). The level of exchangeable phosphorus was very high in the case of the conventional farm and medium on the organic farm. In the case of potassium and magnesium the level of their content was high on the conventional plantations and again medium on the organic ones.

The forecrop on the conventional farm was winter rape. The plantation was fertilized with nitrogen rate of 203 - 213 kg per ha, 90 kg of K₂O and 65 kg of P₂O₅ and 9 - 11 kg of Mg SO₄. The seeds were treated with Baytan Universal 19.5 DS. The weeds were controlled with a mixture of Expert 60 WG, Glean 75 DF and Legato 500 SC (in autumn) and additionally with Granstar 75 WG and Tomigan 250 EC (in spring). The diseases were controlled few times with a fungicides (Sarfun 500 SC, Unix 75 WG, Proline 250 EC, Talius 200 EC, Duet 250 SC, Opera 147.5 SE) and insects with a insecticides (Patriot 100 EC, Fury 100 EC, Cyperkil 25 EC). Moreover grow regulators were applied few times (Cycocel 460 SL, Moddus 250 EC). During the application of mixtures of crop protection agents also fertilizers as urea and magnesium sulphate as well as microfertilizers were added. This is the standard winter wheat growing technology on intensive conventional farms in the region, assuring wheat yields of 8 - 11 t per ha.

On the organic farm winter wheat was grown after potato and fertilized with 25 t per ha of FYM. No seed dressing was applied. Weeds were controlled by harrowing (two times in spring).

In each vegetation period towards the end of tillering stage (BBCH 25 - 27) and in the flowering stage (BBCH 63 - 65), the evaluation of the health state of the winter wheat roots was made. For the study on the health state of roots the MARTYNIUK's (1986) method was used. 100 plants (20 plants from 5 spots of the plot) were taken in random. Single plants were dug out, decessing to the minimum damage to the root system. After the shaking

off the soil, the seedlings or the bottom part of stems along with the roots were placed in foil sacks. On the same day, in the lab the roots were dipped in water and then rinsed under the current of tap water. The degree of the root and foot rot diseases injury was determined according to the scale, where; 0°—healthy plants, 1°—plants very slightly affected (1% - 10% of all roots), 2°—plants slightly affected (11% - 30% of all roots), 3°—plants affected to the average degree (31% - 60% of all roots), 4°—plants strongly affected (over 61% of all roots).

The evaluation of the occurrence of root and foot rot diseases on the leaf sheaths was made towards the end of the tillering stage (BBCH 25 - 27), and at the base of stem in the flowering stage (BBCH 63 - 65) and in the stage of the wax maturity (BBCH 83 - 87). The Poncheta scale, modified by [16], was used for the evaluation, where: 0°—plants without visible signs of disease, 1°—plants slightly affected (1 spot on stem), 2°—plants strongly affected (more spots on stem or 1 spilt all over the stem). To the analysis of the health state of the stem base 100 plants (20 plants from 5 spots of the plot) were taken in random. In the lab the degree of fusarium foot rot (*Fusarium* spp.), eyespot (*Tapesia yallundae*) and sharp eyespot (*Rhizoctonia* spp.) was evaluated. The obtained results were presented in the form of an index of injury, calculated with the Mc Kinney's formula [17].

In lab condition the isolation of fungi living in affected roots and stem base was conducted. With the aim of it during the phytopathological evaluation of the health state of the root system of the wheat, the roots with the symptoms of disease (necrosis and brown spots) were chosen. Further the steps of the [18]'s method were applied. The roots were meticulously rinsed with sterile water, and later sterilized for 30 seconds in 50% solution of ethyl alcohol (C₂H₅OH) and for 30 seconds in 0.1% solution of sodium hypochlorite (NaOCl). After the three times rinsing in sterilized water and drying, 5 mm sections with symptoms of disease were cut out. Such prepared root sections were placed into Petri dishes with potato-glucose agar. The 35 pieces of roots for each of the plots were analyzed. In the case of lack of sufficient number of roots with the symptoms of injury, roots without apparent disease symptoms were used. The samples were incubated in the temperature of 23°C. The grown fungi colonies were transferred on potato-glucose agar slants, then they were reduced to one-spore cultures and recognized by the means of available keys and monographies.

From the collected bases of stems showing the disease symptoms 30 mm pieces with discoloring were cut out and were further processed according to the [19]'s method. The stems sections were rinsed thoroughly in sterile water with a simultaneous shaking off, and later sterilized for 30 seconds in 50% solution of ethyl alcohol (C₂H₅OH) and for 30 seconds in 0.1% solution of sodium hypochlorite (NaOCl). After the three times rinsing in sterile water and drying out in blotting-paper, 1 mm sections were cut out and placed on the PDA, made of 750 ml of distilled water, 250 ml of salt (according to Hansen-Cranner), 1 ml of solution 1 - 2 (Hoagland), 15 g of agar. From each field 35 inoculums were placed and kept in the temperature of 20°C in continuous lightening. After six, eight days of incubation the grown mycelium transfer on potato-glucose agar slants, then they were reduced to one-spore cultures and recognized by the means of available keys and monographies. For this study only the results of fungi isolations from 2007 and 2008 were taken, as the isolations obtained in 2009 have not been marked yet.

3. Results

Every year on each plot of compared farming systems root rot occurred (*Fusarium* spp., *Gaeumannomyces graminis* and other fungi). For the period of 3 years the degree of disease injury on the roots of winter wheat grown in the conventional system in the vegetation period increased, while in the organic one remained on pretty the same level (**Table 1**). On average a lot more affected roots, especially in the flowering stage, occurred on the winter wheat grown in the conventional system.

Fusarium foot rot (*Fusarium* spp.) developed on the wheat during the entire vegetation period. It was the most dangerous root and foot rot disease (the highest indexes of injury). The mean degree of disease injury on leaf sheath was on pretty the same level in the two farming systems, although in investigated vegetation periods differed a lot, whereas at the bases of stems the pathogen was on the higher level on the wheat in the conventional system.

Also eyespot (*Tapesia yallunde*) developed in the entire vegetation period of the winter wheat, but its intensity was much lower than in case of fusarium foot rot. Leaf sheaths of the wheat grown in the conventional system were slightly stronger affected than those grown in the organic system. In the flowering stage the intensity of the disease in both farming systems became equal, while in the wax maturity it was considerably higher in the conventional system.

Table 1. Intensity of root and foot rot diseases on winter wheat (injury index in %).

Disease (Pathogen)	Part of plant	Year	Growth stage	Farming system		LSD 0.05
				Organic	Conventional	
Root rot (<i>Fusarium</i> spp., <i>Gaeumannomyces</i> <i>graminis</i> and other fungi)	Roots	2007		6.5	11.0	
		2008	BBCH	13.3	22.0	1.58
		2009	25 - 27	12.3	20.0	2.75
			Mean	10.7	17.7	4.62
		2007	BBCH	9.3	25.8	3.42
	Leaf sheaths	2008	63 - 65	16.0	26.0	2.13
		2009		6.5	14.3	4.10
			Mean	10.6	22.0	
		2007	BBCH	26.0	18.0	4.89
		2008	25 - 27	12.5	22.5	1.26
Fusarium foot rot (<i>Fusarium</i> spp.)	Stem bases	2009		1.5	4.5	1.73
			Mean	13.3	15.0	
		2007	BBCH	8.5	20.0	3.67
		2008	63 - 65	14.0	19.0	3.58
		2009		4.0	1.5	n.s.
	Leaf sheaths		Mean	8.8	13.5	n.s.
		2007	BBCH	21.0	53.0	6.57
		2008	83 - 87	22.0	23.0	n.s.
		2009		7.0	8.5	n.s.
			Mean	16.7	28.2	
Eyespot (<i>Tapesia yallundae</i>)	Stem bases	2007	BBCH	1.5	6.0	2.34
		2008	25 - 27	13.0	16.0	2.79
		2009		0.5	0.0	n.s.
			Mean	5.0	7.3	
		2007	BBCH	16.0	15.0	n.s.
	Leaf sheaths	2008	63 - 65	11.5	14.8	n.s.
		2009		4.0	6.0	n.s.
			Mean	10.5	11.9	
		2007	BBCH	4.5	25.5	3.39
		2008	83 - 87	19.0	20.5	n.s.
Sharp eyespot (<i>Rhizoctonia</i> spp.)	Stem bases	2009		0.0	6.0	2.00
			Mean	7.8	17.3	
		2009	BBCH	7.0	0.0	4.24
		2007	83 - 87	2.5	6.0	1.17
		2009		19.5	3.0	2.74
		Mean	11.0	4.5		

n.s.—not significant differences.

Sharp eyespot (*Rhizoctonia* spp.) appeared relatively late and occurred only in two years of investigation. The intensiveness of the disease was definitely higher on the organic plots.

Among the affected roots, taken in the stem elongation stage, from the organic system 28 cultures of fungi were isolated, and from the conventional one 24 colonies (Table 2(a)). Cereals pathogenic fungi amounted 35.8% of isolates obtained from the organic system and as many as 66.7% from the conventional system. Among isolates of cereals pathogenic fungi originating from the organic plots *F. equiseti* were predominant (25.0% of all isolates), and from those originating from the conventional ones *F. oxysporum* (41.7%) and *Microdochium nivale* (20.8%).

Table 2. Percent of the pathogenic fungi isolated from infested roots and stem bases of winter wheat in 2007-2008. (a) From roots in BBCH 25-27; (b) From roots in BBCH 63-65; (c) From stem bases in BBCH 83 - 87.

(a)		
Fungi species	Farming system	
	Organic	Conventional
<i>Fusarium equiseti</i> (Corda) Sacc.	25.0	
<i>Fusarium oxysporum</i> (Mart.) Appel et Wollenw.	3.6	41.7
<i>Fusarium sporotrichioides</i> Sherb.	3.6	
<i>Fusarium verticilloides</i> (Sacc.) Nirenberg		4.2
<i>Gaeumannomyces graminis</i> (Sacc.) Arx et Olivier	3.6	
<i>Microdochium nivale</i> (Fries) Cesati		20.8
Percent of all the pathogens	35.8	66.7
Other	64.2	33.3

(b)		
Fungi species	Farming system	
	Organic	Conventional
<i>Fusarium avenaceum</i> (Fr.) Sacc.	2.9	32.0
<i>Fusarium equiseti</i> (Corda) Sacc.	1.5	
<i>Fusarium graminearum</i> Schwabe		4.0
<i>Fusarium oxysporum</i> (Mart.) Appel et Wollenw.	5.9	8.0
<i>Gaeumannomyces graminis</i> (Sacc.) Arx et Olivier	17.6	4.0
<i>Microdochium nivale</i> (Fries) Cesati	5.9	8.0
<i>Rhizoctonia</i> spp.	4.4	
Percent of all the pathogens	38.2	56.0
Other	61.8	44.0

(c)		
Fungi species	Farming system	
	Organic	Conventional
<i>Fusarium avenaceum</i> (Fr.) Sacc.	26.8	28.8
<i>Fusarium culmorum</i> (W.G. Smith) Sacc.	3.6	7.6
<i>Fusarium equiseti</i> (Corda) Sacc.	1.8	
<i>Fusarium graminearum</i> Schwabe	3.6	
<i>Fusarium oxysporum</i> (Mart.) Appel et Wollenw.	5.4	3.8
<i>Fusarium sporotrichioides</i> Sherb.	5.4	
<i>Microdochium nivale</i> (Fries) Cesati		11.5
<i>Rhizoctonia</i> spp.	1.8	1.9
Percent of all the pathogens	48.4	53.6
Other	51.6	46.4

Among the affected roots, taken in the flowering stage, from the organic system 68 cultures of fungi were isolated in all, and from the conventional one 25 colonies (**Table 2(b)**). Cereals pathogenic fungi amounted 38.2% of isolates obtained from the organic system and 56.0% from the conventional system. Among isolates of cereals pathogenic fungi originating from the organic plots *G. graminis* were predominant (17.6% of all isolates), and from those originating from the conventional ones *F. avenaceum* (32.0%).

Among the affected stem bases, taken in the wax maturity stage, from the organic system 56 cultures of fungi

were isolated in all, and from the conventional one 52 colonies (**Table 2(c)**). Cereals pathogenic fungi amounted 48.4% of isolates obtained from the organic system and 53.6% from the conventional system. Among isolates of cereals pathogenic fungi originating from the organic farm *F. avenaceum* were predominant (26.8% of all isolates), and from those originating from the conventional also *F. avenaceum* (28.8%) and *Microdochium nivale* (11.5%).

4. Discussion

The root rot disease occurring on the roots of winter wheat was more severe on crops grown in the conventional system. The increase of disease injury index of crops was observed in this system during the vegetation period, whereas the intensiveness of the disease in the organic system remained on a lower, relatively stable level. According to many authors [1] [2] [13] [18] [20] it is a very dangerous disease, causing decay of seedlings, and thus leading to lowering of yields. The method of preventing this disease in the conventional system is commonly used chemical grains dressing. In turn, in crops grown according to the organic farming principles form their resistance against pathogens among others by mycorrhizal fungi [21] [22]. According to [23] and [24] the fungi develop better in soils of the organic system, which would prove the obtained results.

Also fusarium foot rot and eyespot were more intensive in winter wheat grown in the conventional system. The intensiveness of fusarium foot rot was much higher than eyespot. It confirms the observation of many authors [1] [25] [26], that fusarium foot rot has been the most dangerous among root and foot rot diseases in recent years. The first fungicide application in the conventional system effectively protected the wheat against eyespot up to the flowering stage, whereas in the wax maturity its intensiveness was definitely higher in the conventional system. The second application of fungicides suppressed the development of fusarium foot rot in the wax maturity stage in two out of three investigated years.

Only sporadically occurring in two out of three years of investigation sharp eyespot affected stronger crops grown in the organic system. According to [27] the intensiveness of this disease depends predominantly on the weather conditions in early spring and since the forecrop.

Among the roots and stem bases showing the disease symptoms, more fungi colonies and of greater species diversity were isolated from the organic system, whereas pathogenic fungi for wheat occurred in greater number among the isolates from the conventional system. Among the pathogens fungi of *Fusarium* genus were predominant. Considered by many authors [28] [29] to be the most dangerous among them (*Fusarium avenaceum*, *F. culmorum*, *F. graminearum*, *Microdochium nivale* = *F. nivale*) definitely stronger affected crops in the conventional system. In the organic system a more frequent occurrence of weaker pathogens of *Fusarium* genus was observed. Among dangerous cereals pathogens solely *Gaeumannomyces graminis* stronger affected crops roots in the organic system.

In the case of all root and foot rot diseases of wheat grown in the organic system, an advantageous influence of greater biodiversity and number of various fungi species living in root proximity was noticed as opposed to the conventional system.

5. Conclusions

- 1) Root rot, fusarium foot rot and eyespot affected stronger winter wheat grown in the conventional system.
- 2) Sporadically occurring sharp eyespot developed stronger on crops grown in the organic system.
- 3) Used in the conventional system for the first fungicides application (BBCH 31) protected effectively wheat against eyespot up to the flowering stage.
- 4) Among roots and stem bases more fungi colonies and of greater species diversity were isolated from the organic system.
- 5) Wheat pathogenic fungi constituted majority among the isolates originated from the conventional system and minority in the case of the organic system.

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