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Short communication

PATHOGENICITY OF *FUSARIUM* FUNGI TO CEREAL CROPS

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The pathogenicity of *Fusarium sambucinum* species complex (SC), *F. tricinctum* SC, *F. incarnatum-equiseti* SC, *F. oxysporum* SC, and *F. solani* SC, which are common root rot pathogens in Belarus, was investigated. As many as 288 isolates were obtained from winter cereals (wheat, triticale, rye, and barley) and spring cereals (barley, wheat, triticale, and oats) and tested on seedlings under laboratory conditions. The most pathogenic fungi were *F. sambucinum* SC and *F. tricinctum* SC, while *F. incarnatum-equiseti* SC, *F. oxysporum* SC and *F. solani* SC were weak pathogens. The pathogenicity of *Fusarium* fungi varied between crops. For example, *F. sambucinum* SC was the most pathogenic on winter wheat, triticale, and rye and spring triticale and oats, whereas *F. tricinctum* SC was an aggressive pathogen on winter and spring barley. *Fusarium sambucinum* SC and *F. tricinctum* SC were both aggressive pathogens on spring wheat.

Keywords: *Fusarium tricinctum* species complex, *Fusarium sambucinum* species complex, wheat, triticale, rye, barley, oats

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Introduction

The problem of the Fusarium root rot is one of the most serious in all regions of cereal cultivation (Tunali et al., 2008; Poole et al., 2013; Cromley et al., 2006). This is due to the fact that the disease can be caused by a complex of species, displaying remarkably different environmental requirements, allowing the plants to be damaged under different soil and climatic conditions (Xu et al., 2018).

Species of the genus *Fusarium* differ not only in their requirements for abiotic environmental factors, but also in their pathogenicity, which varies depending on the species (Fernandez et al., 2005; Demirci, Dane, 2003), geographical origin (Motallebi et al., 2015), and specific culture (Arseniuk et al., 1993). This is largely due to significant genetic diversity of isolates even within the same population (Mathy et al., 2019).

Based on long-term studies (2018–2021) of the species diversity of fungi of the genus *Fusarium* causing the root rot, it was found that in the conditions of Belarus the dominant species are *F. equiseti* (Corda) Sacc., *F. oxysporum* Schltdl., *F. culmorum* (Wm.G. Sm.) Sacc., *F. avenaceum* (Fr.) Sacc., and *F. solani* (Mart.) Sacc. (Krupenko et al., 2022ab). The purpose of this work was to assess their pathogenicity.

Materials and Methods

We used monospore isolates of fungi of the genus *Fusarium*, originating from winter (wheat, triticale, rye, barley) and spring (barley, wheat, triticale, oats) grain crops (Table 1). The species affiliation of fungi was determined on the basis of their morphological features (Gerlach, Nirenberg, 1982). Taking into account modern research on taxonomy and the complexity of precise species identification, the studied fungi are designated herein as representatives of species complexes: *F. avenaceum* – as *F. tricinctum* species complex (SC), *F. culmorum* – *F. sambucinum* SC, *F. equiseti* – *F. incarnatum-equiseti* SC, *F. oxysporum* – *F. oxysporum* SC, *F. solani* – *F. solani* SC (Aoki et al., 2014).

Table 1. Characteristics of the isolates under study

Species complex	Number of isolated from different host plants								
	Winter				Spring				All crops
	wheat	triticale	rye	barley	wheat	triticale	oats	barley	
Fusarium tricinctum	–	$5^{1,5,6}$	4^{5}	4^{5}	9^{5}	9^{5}	8^{5}	8^{5}	*47*
Fusarium sambucinum	$10^{1,2,3,4,6}$	$1^{1,5}$	$4^{2,5}$	3^{5}	$4^{2,5}$	$7^{2,5}$	10^{5}	$10^{1,5}$	*49*
Fusarium incarnatum-equiseti	$9^{1,2,3,4,6}$	$7^{1,2,5,6}$	$10^{1,2,5,6}$	$8^{2,5,6}$	$10^{3,4,5,6}$	$7^{4,5,6}$	10^{5}	$10^{1,4,5}$	*71*
Fusarium oxysporum	$8^{3,4}$	10^{1}	$6^{2,4,5,6}$	$10^{1,5,6}$	$9^{1,3,4,5}$	$14^{2,3,4,5}$	7^{5}	$10^{1,4}$	*74*
Fusarium solani	$4^{2,4,6}$	–	$6^{2,4,5}$	$9^{1,2,5,6}$	$6^{2,3,4,5,6}$	$8^{1,5}$	10^{5}	$4^{4,5}$	*47*

The isolates originate from the following regions of Belarus: [1] – Brest; [2] – Vitebsk; [3] – Grodno; [4] – Gomel; [5] – Minsk; [6] – Mogilev.

Таблица 1. Характеристика исследованных изолятов

Комплекс видов	Количество изолятов, выделенных из разных растений-хозяев								
	Озимые				Яровые				Все культуры
	пшеница	тритикале	рожь	ячмень	пшеница	тритикале	овес	ячмень	
Fusarium tricinctum	–	$5^{1,5,6}$	4^{5}	4^{5}	9^{5}	9^{5}	8^{5}	8^{5}	*47*
Fusarium sambucinum	$10^{1,2,3,4,6}$	$1^{1,5}$	$4^{2,5}$	3^{5}	$4^{2,5}$	$7^{2,5}$	10^{5}	$10^{1,5}$	*49*
Fusarium incarnatum-equiseti	$9^{1,2,3,4,6}$	$7^{1,2,5,6}$	$10^{1,2,5,6}$	$8^{2,5,6}$	$10^{3,4,5,6}$	$7^{4,5,6}$	10^{5}	$10^{1,4,5}$	*71*
Fusarium oxysporum	$8^{3,4}$	10^{1}	$6^{2,4,5,6}$	$10^{1,5,6}$	$9^{1,3,4,5}$	$14^{2,3,4,5}$	7^{5}	$10^{1,4}$	*74*
Fusarium solani	$4^{2,4,6}$	–	$6^{2,4,5}$	$9^{1,2,5,6}$	$6^{2,3,4,5,6}$	$8^{1,5}$	10^{5}	$4^{4,5}$	*47*

Примечание – изоляты были выделены из следующих областей Беларуси: [1] – Брестская; [2] – Витебская; [3] – Гродненская; [4] – Гомельская; [5] – Минская; [6] – Могилевская.

Pathogenicity of isolates obtained from a specific plant species was tested on the same crop. Isolates were sown by pinprick on potato sucrose agar (PSA) in Petri dishes and incubated for 7 days at 22–24 °C. Then the seeds of each crop were surface disinfected with 1% sodium hypochlorite solution for 20–30 s, washed twice with sterile distilled water and soaked for 24 hours. After that, the grains were laid out on the surface of 7-day-old colonies, 10 seeds per dish. The experiment was repeated 5 times. In the control, the grains were laid out on the surface of uninoculated PSA. The dishes were incubated for another 7 days under the same conditions, and the degree of damage to the sprouts was assessed using a point scale, where: 0 – healthy sprout; 1 – pinpoint tissue necrosis; 2 – necrosis of about 50% of the area; 3 – complete destruction (Gagkaeva, 2009).

Statistical analysis of the obtained results (calculation of the average lesion score and standard error at a significance level of 0.05) was carried out in Microsoft Excel 2010.

Results and Discussion

Of the five analyzed species (species complexes) of fungi of the genus Fusarium, the most pathogenic were *F. sambucinum* SC and *F. tricinctum* SC: the degree of seedling damage was the same on average for all crops and amounted to 1.8 points (Table 2). At the same time, in our previous studies, as well as according to a number of authors, the pathogenicity of the species *F. avenaceum*, which belongs to *F. tricinctum* SC, is lower than that of the species complex *F. culmorum (F. sambucinum* SC) (Sklimenok, 2015; Fernandez, Chen, 20054; Hudec, 2007). Perhaps, at present, the higher pathogenic properties of *F. tricinctum* SC isolates from the Belarus population have caused an increase in the frequency of its occurrence on grain crops.

In the complexes of *F. incarnatum-equiseti* and *F. oxysporum* species, the pathogenicity was 4.5 times lower – 0.4 points, and *F. solani* SC was the least pathogenic: on average, the seedling damage score was 0.2.

Table 2. Pathogenicity of *Fusarium* fungi for wheat crop sprouts

Комплекс видов	Level of plant infestation, mean score ± standard error ($p<0.05$)								
	Winter				Spring				All crops
	wheat	triticale	rye	barley	wheat	triticale	oats	barley	
Fusarium tricinctum	–	1.0±0.2	1.4±0.2	1.9±0.1	2.4±0.1	1.5±0.1	1.5±0.2	2.2±0.4	*1.8±0.1*
Fusarium sambucinum	1.9±0.1	2.4±0.4	2.0±0.1	0.8±0.1	2.7±0.2	2.6±0.1	2.2±0.1	1.4±0.2	*1.8±0.1*
Fusarium incarnatum-equiseti	0.4±0.0	0.2±0.0	0.1±0.0	0.7±0.0	0.4±0.0	0.3±0.0	0.3±0.1	0.6±0.0	*0.4±0.0*
Fusarium oxysporum	0.3±0.0	0.5±0.1	0.3±0.0	0.3±0.0	0.4±0.0	0.3±0.1	0.3±0.1	0.5±0.0	*0.4±0.0*
Fusarium solani	0.1±0.0	–	0.3±0.1	0.2±0.0	0.2±0.0	0.1±0.0	0.2±0.0	0.1±0.0	*0.2±0.0*

Таблица 2. Патогенность грибов рода *Fusarium* для проростков зерновых культур

Комплекс видов	Степень поражения растений, средний балл ± ошибка среднего ($p<0.05$)								
	Озимые				Яровые				Все культуры
	пшеница	тритикале	рожь	ячмень	пшеница	тритикале	овес	ячмень	
Fusarium tricinctum	–	1.0±0.2	1.4±0.2	1.9±0.1	2.4±0.1	1.5±0.1	1.5±0.2	2.2±0.4	*1.8±0.1*
Fusarium sambucinum	1.9±0.1	2.4±0.4	2.0±0.1	0.8±0.1	2.7±0.2	2.6±0.1	2.2±0.1	1.4±0.2	*1.8±0.1*
Fusarium incarnatum-equiseti	0.4±0.0	0.2±0.0	0.1±0.0	0.7±0.0	0.4±0.0	0.3±0.0	0.3±0.1	0.6±0.0	*0.4±0.0*
Fusarium oxysporum	0.3±0.0	0.5±0.1	0.3±0.0	0.3±0.0	0.4±0.0	0.3±0.1	0.3±0.1	0.5±0.0	*0.4±0.0*
Fusarium solani	0.1±0.0	–	0.3±0.1	0.2±0.0	0.2±0.0	0.1±0.0	0.2±0.0	0.1±0.0	*0.2±0.0*

It was found that pathogenicity varied depending on the crop from which the isolates were isolated. Thus, *F. tricinctum* SC was most pathogenic on spring barley and wheat – 2.2 and 2.4 points, respectively. In *F. sambucinum* SC, pathogenicity was highest in isolates from spring wheat and triticale (the damage score was 2.7 and 2.6, respectively), and lowest in isolates from winter barley – 0.8 points.

In general, the pathogenic properties of *F. sambucinum* SC were higher on all grain crops, with the exception of winter and spring barley, since *F. tricinctum* SC was the most pathogenic on them. Higher pathogenicity of *F. culmorum* in relation to winter wheat sprouts was established in the studies of E. Arseniuk et al. (1993), and according to J. Uoti (1976),

this species was more pathogenic on spring wheat and barley sprouts compared to *F. avenaceum*.

It should also be noted that, for example, on winter triticale, the difference in pathogenicity between the above-mentioned species was significant – 2.4 and 1.0 points, respectively. At the same time, on spring wheat, the damage degree values for these species were close – 2.7 and 2.4 points, respectively. The degree of damage to seedlings in variants with *F. incarnatum-equiseti* SC was maximum on winter barley (0.7 points), while it is important that on this crop, the pathogenicity of *F. sambucinum* SC and *F. incarnatum-equiseti* SC was close – 0.8 and 0.7 points, respectively. There are conflicting data on the pathogenicity of the *F. equiseti* fungus in the literature: according to some data, the fungal isolates were non-pathogenic (Gebremariam et al., 2017), while according to others, they were pathogenic (Demirci, Dane, 2003).

Pathogenicity of *F. oxysporum* SC on the analyzed crops was low and reached maximum values on winter triticale and spring barley. For *F. solani* SC, the damage degree values on all analyzed crops were also low – up to 0.3 points on winter rye. At the same time, in recent years, the frequency of occurrence of *F. incarnatum-equiseti* SC, *F. oxysporum* SC and *F. solani* SC on the root system of grain crops throughout the Republic of Belarus has increased. According to recent data, *F. oxysporum* acts as an endophyte in the plant (Demers et al., 2015) and, if it colonizes the plant first, can to a certain extent restrain the penetration of other species (Aime et al., 2013; Benhamou, Garand, 2001).

Taking into account the obtained data on the pathogenicity of *F. incarnatum-equiseti* SC, *F. oxysporum* SC and *F. solani* SC, it can be assumed that they also act primarily as endophytes on the roots of grain crops in the geographic area of the study, though this requires further research.

Conclusion

The conducted studies allowed us to establish different pathogenicity of *Fusarium* spp. isolates from Belarus in relation to winter and spring grain crops. Thus, *F. sambucinum* SC was the most pathogenic for spring wheat and barley, *F. tricinctum* SC – for spring wheat, *F. incarnatum-equiseti* SC – for winter and spring barley, *F. oxysporum* SC – for winter triticale and spring barley, *F. solani* SC – for winter rye.

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Краткое сообщение

ПАТОГЕННОСТЬ ГРИБОВ РОДА *FUSARIUM* В ОТНОШЕНИИ ЗЕРНОВЫХ КУЛЬТУР

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Изучена патогенность грибов *Fusarium sambucinum* SC, *F. tricinctum* SC, *F. incarnatum-equiseti* SC, *F. oxysporum* SC и *F. solani* SC, которые доминируют среди возбудителей корневой гнили в Беларуси. Было выделено 288 изолятов из озимых (пшеница, тритикале, рожь, ячмень) и яровых (ячмень, пшеница, тритикале, овес) зерновых культур, которые протестировали на проростках этих же растений в лабораторных условиях. Наиболее патогенными были *F. sambucinum* SC и *F. tricinctum* SC, тогда как *F. incarnatum-equiseti* SC, *F. oxysporum* SC и *F. solani* SC оказались менее патогенными. Патогенность видов значительно варьировала в зависимости от культуры: *F. sambucinum* SC был наиболее патогенным для озимых пшеницы, тритикале и ржи, а также яровой тритикале и овса, а *F. tricinctum* SC – для озимого и ярового ячменя. Для яровой пшеницы патогенность *F. sambucinum* SC и *F. tricinctum* SC была высокой.

Ключевые слова: *Fusarium tricinctum* species complex, *Fusarium sambucinum* species complex, пшеница, тритикале, рожь, ячмень, овёс

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